The Engineer

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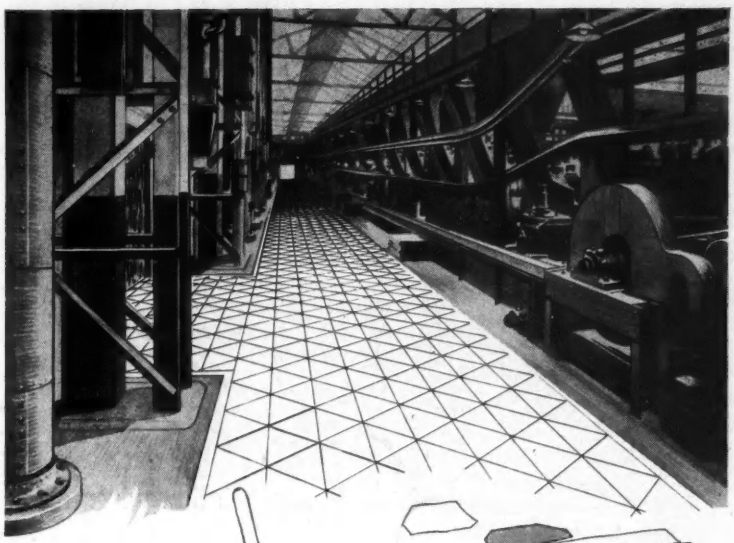

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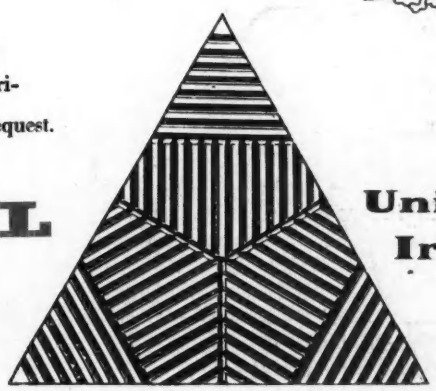

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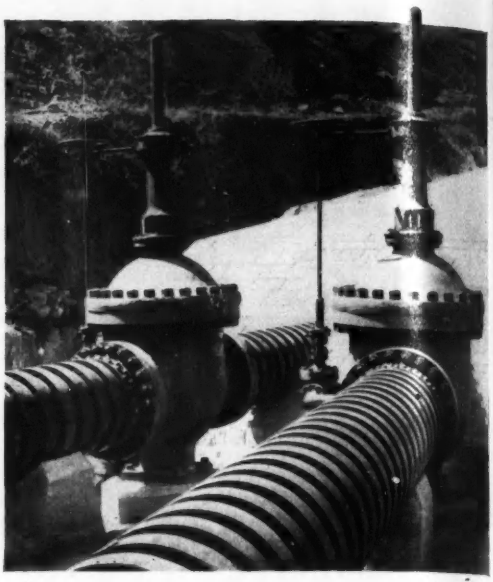

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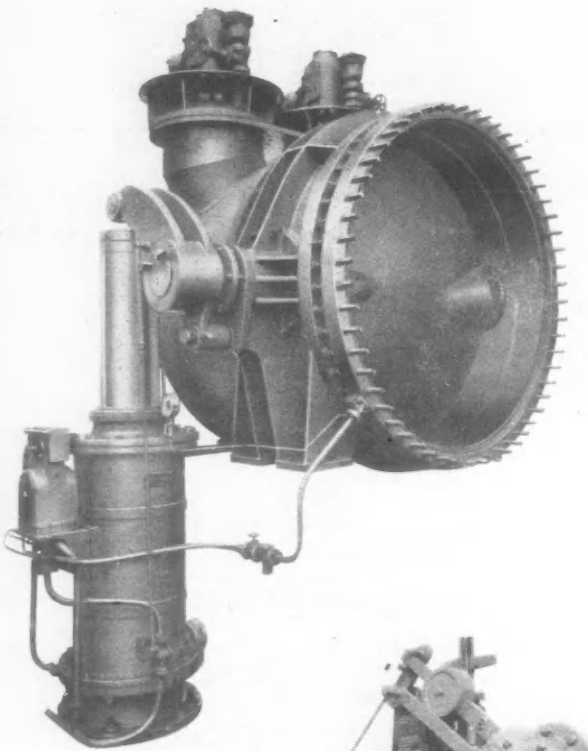

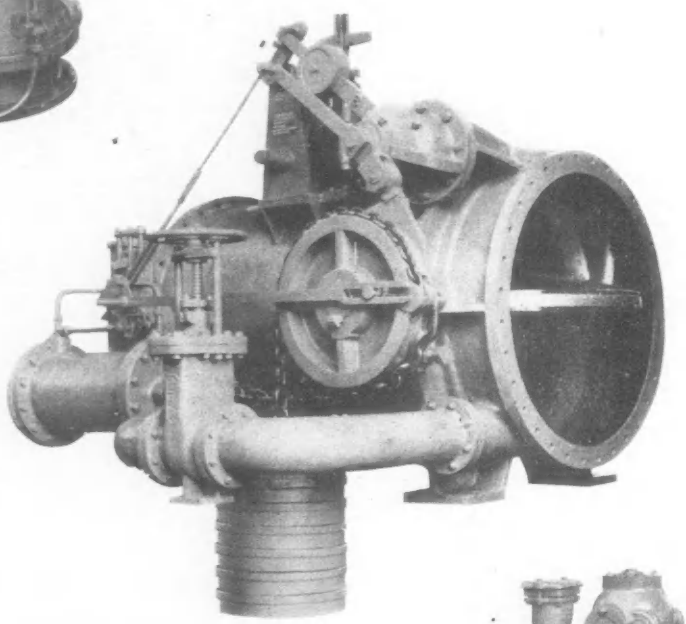

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THE ENGINEER

VOL. 202 No. 5256 OCTOBER 19, 1956

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FURTHER EXPANSION AT IMPERIAL COLLEGE

Since last we wrote in these columns on the enlargement of the Imperial College in South Kensington, London, a new and important development, foreshadowed at that time, has taken place. The authorities now plan the acquisition at an early date of almost all of the four sides of the square known as Princes Gardens, lying just on the far side of Exhibition Road, which it seems can be purchased for the College through the good offices of the University Grants Committee. This action will enable work to start almost at once on the East and South sides of the square for halls of residence, with over 400 study bedrooms, together with the necessary refectory and common-room facilities. The ideal of there being combined in the one College education at undergraduate and post-graduate level in science and technology, with space and equipment for basic research, is greatly advanced when there can be included adequate facilities for students and staff to mix easily for debate, in committee work, and in common rooms and in refectories. By this enlargement of the College area the pressure on the old island site will be materially lessened and an altered plan for the whole has become possible. Work on some of the new buildings already under erection on that site is going busily forward, and the new one for Aeronautics may indeed be completed by the contractors before the next meeting of the College Board of Governors.

It was in January, 1953, that the Government was impelled by the sheer pressure of what was happening in other parts of the world to ask the Board of Governors of the College to take the steps necessary to increase the number of its students, which then stood at about 1650, to a very much larger figure; indeed, the aspiration was expressed that by 1962 the number might rise as high as 3000. This meant asking the Governors almost to double the then student population. Besides a corresponding increase in the size of the teaching staff, it required the adoption of a considerable building programme. The action taken was rapid and, in little more than three years, the student numbers have risen to 2250, with a proportionate increase in the size of the staff, and at least some moderate addition to the accommodation available. The remarkable " hump " in this country's birth-rate, which stood at the low figure in 1941 of 700,000, but rose within the next six years to over a million, may well cause a temporary congestion in many educational establishments in this country, but should tend to aid the Imperial College in gathering a harvest of able young men. All this, of course, involves a large increase in the annual monetary grant to be provided by the University Grants Committee, but the Treasury was very ready to give the necessary authority; and building work started as soon as the architectural plans were ready. Much has been done and some of the buildings have reached completion. As is well-known, the initial decision was to make use of what is known as the " island site," namely, almost all of the rectangle south of Prince Consort Road and bounded by Exhibition Road, Queen's Gate and Imperial Institute Road. But when one speaks of use being made for these purposes of this particular site one must remember that there is no intention to disturb the present location of the Royal College of Music, and that there are certain buildings on the south-west corner in private residential occupation and likely so to remain for the present, at any rate. The main purpose now is to aim at the provision of a College of Science and Technology which shall be second to none in any part of the world. But in pursuing this conception provision needs to be made to allow of the College being kept running continuously during the construction period — no simple task when the student body is in rapid growth. Faculties, too, grow in numbers and if the estimated (1955) proportion of workers in technical occupations be taken, as a rough and ready guide to the probable call on College Faculties, it is germane to note that about 25 per cent are estimated to be in engineering industrial establishments of one kind or another, about 6 per cent in mining, agriculture and forestry, and about 9 per cent in building and civil engineering. The College has also made early plans for the arrival of the young men who hope to share in the future development of nuclear energy for civil purposes; and this may become a growing feature in the life of the College.

ARE GEAR STANDARDS WANTED?

It has for long been common knowledge that the British Standards Institution has been experiencing great difficulty in attempting to revise three of its gear Standards. The Standards concerned are B.S. 436, " Helical and Spur Gears," last revised in 1940; B.S. 721, " Worm Gearing," last amended in 1941, and B.S. 545, " Bevel Gears," last revised in 1949. The members of the committee studying these Standards appear to be in full agreement only upon one point about them. That sole point of agreement is that revision is essential. It is not our part editorially to attempt to intervene technically in what amounts to a highly specialised discussion. But on page 547 of this issue we print an article by Dr. H. E. Merritt summarising the situation as it exists to-day as seen by him. We asked him to contribute that article to our pages because it seemed to us that if the British Standards Institution was making no progress in attempts to revise the Standards then it was desirable that the whole matter should be ventilated more widely. If, for example, the existing Standards have so few virtues that a man ordering gears would only be hampering a gear manufacturer by insisting that the gears should be made to British Standards, and if a non-specialist desiring to make gears will not necessarily be best serving his purposes by following those Standards, ought they not to be withdrawn whether or not new and improved Standards can be devised to replace them ?

For to have in existence Standards that nobody except those ignorant of the facts would ever think of following is not merely Gilbertian, but actively damaging to the prestige of the British Standards Institution. Yet that, so it appears to us, may represent very nearly the existing picture.

In attempting to devise replacements for the existing Standards the Institution appears to have experienced the difficulty that there is not merely a cleavage of opinion within the relevant committee, but something nearer to a complete shattering of opinion. Agreement cannot be reached even amongst small groups on the committee far less amongst any substantial proportion of the membership. No unifying idea about the purpose the Standards might serve has apparently emerged from discussion, with the natural consequence that no member has seen any reason for budging from his initial opinions. Under these circumstances, it seems hopeless to ask the committee to continue to struggle. It must be better to bring the whole matter into the open. For there may emerge from wider discussion some unifying idea about the functions of the Standards which would lead to agreement about their revision. Or, as a consequence of wider discussion, it may, for example, appear that, even if only for the guidance of the few and even if it proves impracticable to draw up Standards reflecting the best modern practice, Standards could still serve a useful purpose, but only, of course, if the limitations are made clear to prospective users. Alternatively, it may be revealed that in reality very few people are interested anyway. If so, the three Standards might just as well be expunged from the records and all further effort to revise them be given up.

GAS TURBINE AT SEA

Last week there visited this country an American merchant ship which relies for propulsion solely upon an open-cycle two-shaft turbine engine—the first ship in the world of any size to do so. The ship concerned is a "Liberty" ship, of which hundreds were built during the war. Large numbers of these vessels are now laid up across the Atlantic and form a reserve fleet only likely to see service again in an emergency. For, compared with present-day merchant ship speeds of 15 knots, they can only steam at 10 knots and their engines are steam reciprocators. Four of these ships have become the subject of an experiment now being carried out by the U.S. Office of Ship Construction and Repair, a governmental organisation. All have had the original engines removed. One, without other changes, nor even apparently the installation of new boilers, has been converted to steam turbine drive. Experience with her has shown that if higher speeds are to be obtained without loss of sea kindliness, hull modification is essential. Consequently all the three remaining ships have had, or will have, their bows lengthened. One of the remaining three ships has been equipped with geared diesel drive; in another, the one that recently visited these shores, the original 2500 h.p. steam engine has been replaced by a two-shaft open-cycle gas turbine of 6000 h.p., built by the General Electric Company of America; and the fourth, now undergoing conversion, will also have a gas turbine engine, but the gas generator will be of the free-piston design. The initial objective seems to have been to study the possibility of bringing these old vessels back into economic service. But, in fact, the value of the experiment is more likely to lie in the possibility it will provide of evaluating the economics of the four systems of propulsion.

So far little has been learned. It is already known from experience in this country with the "Auris" that marine gas turbines can be built with the high degree of reliability in service that is demanded of marine engines. What is needed now is an assessment of economy in operation. But all that the American vessel has so far done is to cross the Atlantic using diesel oil as a fuel. Owing to its low thermal efficiency it is very improbable that a gas turbine using such a fuel could compete with diesel engines. It is intended, however, when more experience has been gained, to burn bunker oil instead, and part of the interest of the installation lies in the means adopted for treating the oil with Epsom salts as a cleaner and additive. The use of that fuel, assuming it leads to no appreciably increased maintenance costs—as it does with the diesel—might make the gas turbine an economic proposition. But it is far too soon yet, it will be observed, to draw any conclusions. All that is known is that on trials the ship attained a speed exceeding 18 knots, the machinery developed 7575 h.p. and the fuel consumption was in the neighbourhood of 0·53 lb per s.h.p. hour. Another interesting point about the ship is that the well-known problem of reversal with a gas turbine drive is solved by the use of a reversible pitch propeller.

In this country there is no exactly comparable experiment to be recorded. But the "Auris," in which, it will be remembered, a B.T.H. gas turbine of 1200 b.h.p. replaced one of the four original 1105 b.h.p. Hawthorn-Sulzer diesels, is now being converted by the Shell Group. There will be a single open-cycle gas turbine, the manufacture of which is well advanced at the B.T.H. works, and the drive will be transmitted to a conventional propeller through a Pametrada hydraulic astern torque converter system. Less money is being expended here than in America and the Government is not involved. Yet we wonder whether in reality the experiment with the "Auris" may not prove rather more valuable than the more lavish American affair. For the question that really needs to be determined is whether the gas turbine can compete economically with the diesel whether the latter runs on diesel oil or on bunker oil. It is very unlikely—at least in the more immediate future—that it will be capable of competing with steam machinery at the higher powers. The performance of the "Auris" with diesel-electric propulsion is already on record. The installation of gas turbine engines in the same vessel will permit comparisons to be made as directly as they ever can be made at sea. How much we wish, however, that the comparison could be carried further, and that a nuclear power plant could be designed and installed in a sister vessel. Were the Government to intervene—and why should it not, since nuclear power has promising prospects for the propulsion of naval vessels—could not that experiment also be carried out?

The Engineer
100 Years Ago
(OCTOBER 17, 1856)

"THE HOUSELESS BOARD OF WORKS"

"The Metropolitan Board of Works first occupied itself on Friday last by discussing the question of site for the erection of offices for the Board's exclusive use. Advertisements had been inserted in the daily papers, soliciting offers from the public. Sites appear, however, to be scarce; for the offers were few, and not desirable. The Board was not disposed to accept the proposal of a certain landowner, who appeared desirous that the head-quarters should be transferred from the Guildhall to the neighbourhood of the New Cut. Neither was the offer of an upper floor at the corner of Chancery-lane, 'over a shop,' more acceptable to our local parliament. In this position of affairs, the old premises in Greek-street presented themselves as most eligible, and Mr. Leslie gave notice of a motion..... 'that all previous orders on the whole subject be rescinded, so as to enable the Board to decide, that the 9,940ft of the ratepayers' freehold property in Greek-street, be adopted for the permanent use of the Board, and that a premium of one hundred guineas be offered by public competition, for plans which shall include a board-room, equal in dimensions, but better lighted and ventilated, than the Council-chamber of the City of London.'

"Two questions suggest themselves to us at the moment, and we refer them to the consideration of the Board itself: first—Is it worth while erecting a new building, at considerable cost to the ratepayers, when it is more than probable that, before it can be completed, the Metropolitan Board of Works will have become an Institution of the past? Secondly—At best, would not a suite of rooms in Somerset House answer the purpose as well as a new building? A board-room overlooking the river would be well lighted, and Mr. Leslie's views as to ventilation might be fully carried into effect. What could be more delightful? To be sure, the main sewer empties itself somewhere thereabouts, but that is of little consequence we opine."

A Seven Day Journal

Aircraft Procurement

On Wednesday this week Air Commodore F. R. Banks, addressing the Royal Aeronautical Society, called for the halving of the time taken to get an aircraft into production, and pointed out that the North American "Super Sabre" had passed from design to delivery of 200 aircraft in little more calendar time than the "Sabre Jet," although 5,000,000 instead of 2,000,000 man-hours were consumed. The result of such indefensible decisions as led to four bombers—"Sperrin," "Valiant," "Vulcan" and "Victor"—being built, was that the equipment of the Royal Air Force was inferior to that used in America, Russia and Sweden. He believed that an Air Staff requirement had to be considered by the Defence Research Policy Committee, the Air Defence Committee, and the Cabinet Defence Committee before reaching even the Ministry of Supply. He did not consider it practicable to eliminate the Ministry of Supply, which justified itself by carrying out research and development. For civil aircraft a firm would need to turn out ten every month of large (over 60-ton) transports to be economically successful, so that much larger production units than at present existing were necessary. The Air Commodore pointed out that engines were even more expensive, slow, and difficult to develop, and that a great part of the troubles encountered could be attributed to insufficient hours' actual flying. He estimated that to build a supersonic transport would require £50,000,000 and ten years. Finally, he pointed out that the tardiness and arbitrary reductions in contracts affecting military procurement indicated a belief in high places that "war may never happen." A thoroughly detailed appendix covering the Boeing B17, B29, B47, and B.52 ("Flying Fortress," "Super Fortress," "Stratojet," "Stratofortress") showed that over twenty years the cost per pound of bomber had risen slightly, but that the cost per pound of "useful" load had tended downwards (allowing for inflation), while the cost per ton-mile per hour was reducing markedly with the increase in aircraft size.

Sir Alfred Herbert Travelling Scholarship

To mark the occasion of Sir Alfred Herbert's ninetieth birthday, and in recognition of his outstanding services to the machine tool industry, the Machine Tool Trades Association has instituted a scholarship to assist engineering students to add to their knowledge. This scholarship, the annual value of which will be about £125, is to enable students of Coventry Technical College to extend their knowledge of machine tool design and manufacture, and of production methods, by visiting engineering works in the British Isles or on the Continent. The award will normally be made in the autumn by trustees, and it will include the presentation of a medal. Candidates between the ages of twenty-one and thirty on July 31st of the year of the award will, in general, be eligible. The minimum educational standard will be that corresponding to the requirements for corporate membership of the Institution of Production Engineers. In addition to full details of education and training, candidates will be required to submit a proposed programme for the tour. On completion of his tour the holder of the scholarship will be expected to submit a report to the trustees. It is stated that the following have undertaken to serve as trustees :—Mr. B. C. Harrison (director of Alfred Herbert, Ltd.), Mr. J. G. Petter (director of Cincinnati Milling Machines, Ltd.), and Mr. S. J. Harley (chairman and managing director of Coventry Gauge and Tool Company, Ltd.).

Visit of British Engineers to Russian Hydro-Electric Schemes

The British Council informs us that it has arranged for a group of six British engineers to visit Russia for two weeks, to study that country's hydro-electric industry. A return visit by a group of Soviet engineers to this country is expected next summer. The British group left for Russia last week. They are as follows :—Sir John Hacking (Messrs. Merz and McLellan), Mr. A. A. Fulton (North of Scotland Hydro-Electric Board), Dr. S. P. Hutton (Mechanical Engineering Research Laboratory), Dr. W. MacGregor (G. Wimpey and Co., Ltd.), Mr. R. W. Mountain (Messrs. Kennedy and Donkin), and Mr. H. West (Metropolitan-Vickers Electrical Company, Ltd.). They will visit major hydro-electric sites, research institutions and a works where water turbines are built.

Road Statistics

The 1956 edition of "Basic Road Statistics," just issued by the British Road Federation, reviews the Minister of Transport's plans for highway development, which are at present scheduled to cost £42,000,000 in 1958–59 for new construction, and should include commencement of the London-Yorkshire motorway in 1956–58. Last year expenditure on roads approached a record £100 million, somewhere near the receipts from motor taxation before the resurgent increase from 1951 onwards. Taxation last year totalled £480 million, receipts from fuel tax, licences and purchase all being higher than ever before, purchase tax having risen from £91,000,000 to £124 million : the total represented 9·8 per cent of the national revenue. Total fuel consumption continued to rise, being now nearly three times that of 1928 ; compared to that year, the number of fatalities on the roads has altered little over the intervening decades, but injuries are 60 per cent higher and increasing sharply. The cost to the community of road accidents was estimated at £171 million last year, predominantly for compensation for personal injury. The proportion of diesel engines in newly registered goods vehicles is rising markedly, reaching 20 per cent in 1955, but in that year less than 10 per cent of all goods vehicles were diesel engined. The booklet includes historical accounts of the evolution of fuel tax and the vicissitudes of the road fund, and an outline of legislation since 1930. Northern Ireland is treated separately.

North East Coast Institution of Engineers and Shipbuilders

The opening general meeting of the seventy-third session of the North East Coast Institution of Engineers and Shipbuilders was held last Friday. The proceedings included the installation of the new President, Mr. R. C. Thompson, and the delivery of his presidential address. In the course of his remarks Mr. Thompson recalled that his grandfather was the fifth president, and he went on to comment that problems of that day and age were still largely unresolved. Referring to co-operation between management and men, the president remarked upon the responsibilities of shipbuilders and the irresponsibility of many of the workers, who staged unofficial strikes, indulged in go-slow tactics, limited output, put embargoes on overtime and even maliciously caused last minute postponement of launches. Such conduct, he continued, caused difficulties which undermined and impeded management in carrying out its job to organise production. An instance of the ridiculousness of demarcation practices was given and attention called to damage caused by lack of co-operation ; the president recalled that his grandfather, over sixty years ago, had written that the interests of capital and labour were identical and that strikes only aided foreign competition to our own detriment. He regretted that the solution of co-operation problems had become a political matter and roundly denounced proposals to nationalise the industry, since nationalisation would lead to higher costs and the loss of export orders, accompanied by contraction of the industry. Turning to technical matters, Mr. Thompson wanted the construction rules modified to give the designer greater scope in determining scantlings. He also appealed for a better regulated supply of steel to avoid delays in construction and suggested that it would be more economical for the steelmakers to remove mill scale from plates and sections. The large capital investment represented by reconstruction schemes called for the maximum use of the equipment installed for economic production, and he suggested that staggered holidays would help towards that objective. The incidence of taxation, Mr. Thompson continued, meant that one-third of the price paid for the ship was returned to the Government in taxes. He thought that profits ploughed back into the business should be exempt.

Hydro-Electric Power in Ontario

We have received the report for the year 1955 of the Hydro-Electric Power Commission of Ontario. Nineteen-fifty-five was the Commission's jubilee year, and so attention is drawn to the progress made in its area, over the past fifty years, in building up a cheap and comprehensive service of electrical power supply, based primarily on water power. The rate of expansion in the Commission's system can be gauged from comparison with 1954, which shows an increase of 9·6 per cent in the "dependable peak capacity" and of 18·6 per cent in the total net output. However, 15 per cent of the total net output was purchased. The Commission itself had in operation during 1955 sixty-five hydro-electric and five thermal-electric generating stations, their total installed capacity being 4530MW and their output for that year 22,468 million kWh. The major interest in engineering construction during the year was centred on the St. Lawrence River works, which are being built jointly with the Power Authority of the State of New York and on the pumped storage scheme forming part of the Sir Adam Beck-Niagara generating station No. 2. The latter was described in The Engineer of October 1, 1954. The St. Lawrence project involves installation of 820MW in sixteen sets (the Commission's share of the total), at a rated head of 81ft. The station is being built about 2 miles west of Cornwall on the International Rapids section of the river, and is of course, part of the larger seaway scheme. During 1955 extensive cofferdams were built and dewatered and excavation work was in progress within them, on the Canadian shore.

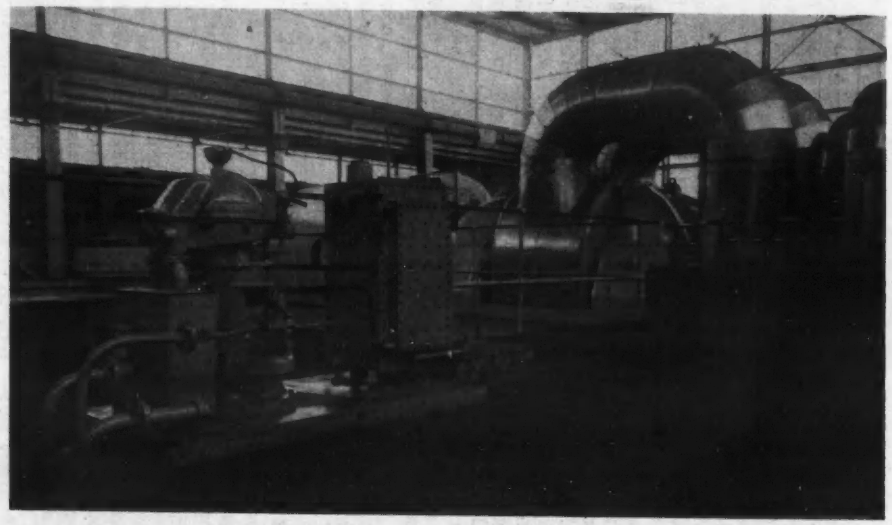


Fig. 16—In the background is one of the four 23MW turbo-generators. In the foreground is the associated centrifugal purifier for the oil which operates the h.p. and l.p. governor valves, the emergency stop valves and the steam pressure regulator

Fig. 17—On the left is a "dump" condenser capable of taking the steam by-passed from two turbines. When the turbo-generators are loaded normally the steam from each turbine is dealt with by the usual form of condenser which can be seen on the right

Fig. 18—Control room for No. 1 reactor. The burst slug leak detection recorders are mounted on the left-hand wall panel. On the right-hand wall panel there is a mimic diagram of the reactor and the four associated heat exchangers

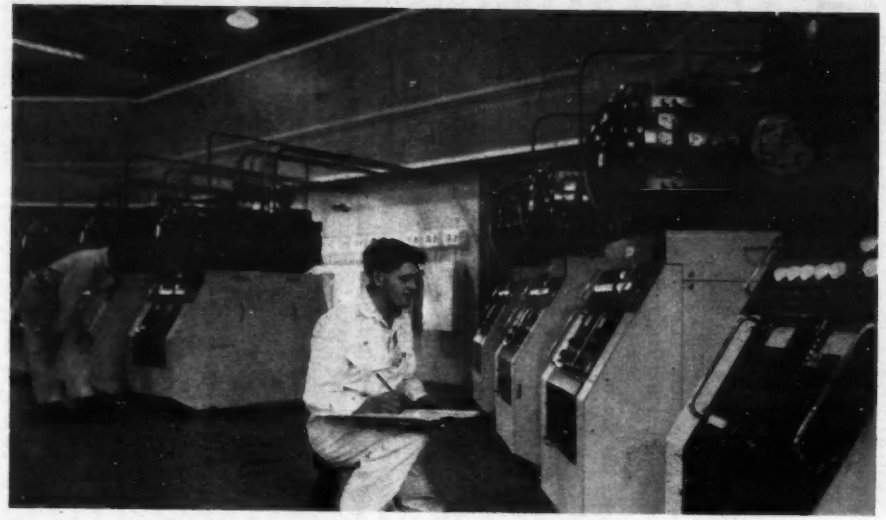


Fig. 19—A group of precipitator units in the "sniffer" or gas sampling control room. Gas is sampled from each of the 1696 fuel element channels in turn and is monitored to give warning of any increase in radioactivity caused by a punctured fuel element can

Calder Hall Power Station

No. III—(*Concluded from page 503, October 12th*)

Calder Hall "A" power station was formally opened by Her Majesty the Queen on October 17th, three and a half years after the design team started work on the scheme. It is the first nuclear power station to generate electricity on an industrial scale. The main plant consists of two gas-cooled graphite-moderated natural uranium reactors, the heat from which is taken by the coolant, carbon dioxide under pressure, to heat exchangers where steam is generated for the four 23MW turbo-alternators. The reactor is designed for the production of plutonium as well as the generation of electricity. An identical station, known as Calder Hall "B," is under construction on an adjoining site and is due to be completed in 1958.

THE turbine room at Calder Hall is sited between the two reactors and can be seen on the right of Fig. 20 immediately behind the administration building and the outdoor substation. There are four Parsons turbo-generators in the turbine room; each has an output of 23MW. The plant is so arranged that two turbo-generators with two surface condensers, two main line de-aerators and one "dump" condenser with its associated desuperheaters, work in conjunction with each reactor. The generators are of standard design, each with a continuous maximum rating of 23MW at 11·5kV and 0·8 power factor. They operate on a closed air ventilation system, the cooling air being provided by two motor-driven fans working in parallel when the machine is fully loaded.

Turbines

Although the turbo-generators may be classed with the more orthodox items of plant at Calder Hall, there are some interesting aspects of design determined by the reactor and the unusual steam conditions. In last week's article we explained, on page 500, that the dual pressure steam cycle was preferred to the single pressure cycle because it offered a much higher overall efficiency at the required gas temperature at the reactor inlet.

Accordingly the turbines are designed to accept steam at two different pressures from the two independent steam circuits in the heat exchangers. About 77 per cent of the total quantity of steam taken by each turbine is supplied to the first stage at a pressure of 185 lb per square inch gauge and a temperature of 590 deg. Fah. After the fifteenth stage a further supply of steam, amounting to about 23 per cent of the total, is admitted to the turbine at a pressure of about 40 lb per square inch gauge and a temperature of 340 deg. Fah. At the turbine exhaust flange the vacuum is 1·75in Hg. abs. and the estimated wetness of the steam is 11 per cent.

The turbine that was designed to meet these conditions is a two-cylinder tandem machine, which is illustrated in Fig. 16 and in the colour plate facing page 464 *ante*. It consists of a single-flow h.p. unit solidly coupled to a double-flow l.p. unit, which is provided with two exhausts to give ample exhaust area with a comparatively low blade speed.

Throughout the turbine the blading is all reaction, the material being stainless iron, and the blades in the two final stages of the l.p. machine being fitted with erosion-resisting tips. The two steam supplies are taken to separate high-pressure and low-pressure steam chests which are arranged one on each side of the turbine; each chest has an emergency stop valve and a governor valve.

Since the full heat output from the reactors (and, therefore, the heat exchangers) must be absorbed continuously, it is convenient for the turbines to be operated normally under steam pressure control, this being the most effective way of controlling the temperature of the coolant circulating between the heat exchangers and reactor. In the event of the reactor heat output exceeding that which can be absorbed by the turbines the surplus steam is automatically passed to a "dump" condenser, which is described below.

When the set is being started up the high-pressure governor valve is under speed control and at this stage any surplus steam is discharged to the "dump" condenser. As soon as the load on the turbine is sufficient to absorb all the h.p. steam generated in the heat exchanger, pressure control is automatically asserted and the h.p. steam admitted to the turbine is controlled to keep the boiler pressure sensibly constant. The consequent adjustment of the steam demand from the l.p. cycle helps to keep a constant gas temperature at the reactor inlet. There is also a throttling control valve in the l.p. steam feed from the heat exchanger. It is pressure-regulated to maintain constant l.p. steam pressure and it can be adjusted to raise the pressure when the steam flow falls off. In this way the pressure can be adjusted to keep a constant gas temperature at the reactor inlet. To protect the set in the event of loss of electrical load, overriding speed controls are provided on both the h.p. and l.p. steam feeds. The h.p. and l.p. governor valves, emergency stop valves and the steam pressure regulator are operated by power oil supplied by a gear type oil pump mounted on a cross shaft driven by worm gearing from the steam end of the high-pressure turbine shaft. A lubricating oil pump supplying oil to the oil coolers and bearings is mounted on the same cross shaft.

On each set the steam from the l.p. turbine is normally exhausted into a condenser (on the right of Fig. 17), which represents orthodox power station practice and has a cooling surface of 32,500 square feet, using 1in diameter tubes which are expanded into the tube plate at one end and sealed off with metallic packing and ferrules at the other end.

Main Particulars of Turbo-Alternators at Calder Hall Power Station

Number of sets per reactor	2
Maximum continuous rating at 0·8 p.f. lagging	23MW
Speed	3,000 r.p.m.
Generator voltage	11·5kV, 3 phase, 50 c/s
High-pressure steam pressure at turbine stop valve	200 lb per square inch abs.
H.p. steam temperature at stop valve	590 deg. Fah. (310 deg. Cent.)
H.p. steam per set (77 per cent total)	198,000 lb per hour
L.p. steam pressure at stop valve	53 lb per square inch abs.
L.p. steam temperature at stop valve	340 deg. Fah. (171 deg. Cent.)
L.p. steam per set (23 per cent total)	59,300 lb per hour
Flow rate to condenser, per set	257,300 lb per hour
Absolute pressure at turbine exhaust	1·75in Hg
Maximum cooling water temperature	85 deg. Fah. (29·4 deg. Cent.)

To consume any steam in excess of normal load requirements and to allow for the possibility of the station being suddenly disconnected from the grid when on load, two special "dump" condensers are installed; each is capable of taking the whole of the steam diverted from two fully loaded turbo-generators. Primary desuperheaters using mechanically and thermostatically controlled spray nozzles reduce the temperature of the steam entering the "dump" condenser to about 300 deg. Fah. Secondary desuperheaters are fitted in the top chamber of the condenser to reduce the temperature of the steam still further to saturation point.

One of the two "dump" condensers can be seen on the left of Fig. 17.

Fig. 20—Calder Hall power station. In the centre is one of the reactors and, on the right, the turbine room and administrative block. In the foreground is the 132kV substation

Burst Fuel Slug Detection

Much of the instrumentation at Calder Hall power station is novel both in function

and design. One of the more interesting examples is that which has been developed by Plessey Nucleonics, Ltd., in collaboration with the U.K. Atomic Energy Authority to provide automatic warning of any excessive radioactivity caused by faulty fuel containers in the reactor. By this means a defect, such as a punctured fuel can, may be detected in time to prevent fission products from escaping into the gas coolant circuit and contaminating it.

In principle the system of detection is to take from each of the fuel channels in turn, small samples of the coolant gas circulating around the fuel element cans and to monitor these samples for radioactive components, using electrostatic precipitation and scintillation counting, as described more fully below. A block diagram of the system is given in Fig. 21. For the gas sampling, the 1696 fuel channels in each reactor are divided into eight separate areas, each controlled by a 54-point gas sampling plant which registers back to a central control room. From each of these areas, 212 gas sampling pipelines are led via steel plugs through the pressure vessel and biological shield to manually-operated cocks which reduce the number of channels to fifty-three by combining them in groups of four. Each of the fifty-three pipe-lines is connected to the inlet ports of a 54-way selector valve, which in turn links them to outlet ports. Samples of the gas are taken from each inlet port every twenty-seven minutes, the valve remaining stationary at each inlet for twenty-eight seconds and taking two seconds to travel between ports. The 54-way selector valve of each area is connected by a single pipeline, via a cooler and a filter, to remove any entrained uranium oxide particles, to its own precipitator unit.

When a fuel container is damaged, fission products, some of them in gaseous form, escape into the main coolant stream. The particles are arrested by the filter, but some of the radioactive gases pass on into the precipitator unit where they decay and become deposited by electrostatic precipitation on to a wire which remains stationary for twenty-eight seconds during the sampling period. At the end of the sampling period, the portion of wire carrying the radioactive deposit travels for two seconds to a scintillation counter, remaining there another twenty-eight seconds for checking. This scintillation counter operates a rate-meter which in turn gives an indication on a 54-way recorder in the control room and if a high radioactive count is registered a warning bell is operated in the control room.

While this piece of wire is being checked for radioactivity, a gas sample is being taken from the next inlet port on the selector valve and the products are being deposited on another part of the wire. No part of the wire is used more than once in thirty minutes, thus allowing long-lived activity to decay.

Overall sampling of the gas coolant in the reactor is governed by a 9-point gas sampling plant consisting of eight additional pipelines (four from the inlet and four from the outlet gas ducts) joined to the eight inlet ports of a 9-way selector valve. Each inlet port is connected in turn with an outlet port and the valve remains stationary for a 28-second sampling period at each inlet and also takes two seconds to travel between ports. Each inlet is checked, therefore, once every four-and-a-half minutes. This 9-way selector valve is connected, via a cooler and filter, by a single pipeline to a duct precipitator unit, similar in operation to the others mentioned. Any suspect pipeline can be sampled continuously by diverting it to one of two spare precipitator units which, operating in conjunction with a single-point recorder in the control room, constitutes a single-point gas sampling plant.

The 54-way selector valve consists of a body with fifty-three inlet ports, the fifty-fourth position having an internal transfer port which maintains gas flow through the valve. Each inlet port is connected in turn with an outlet port by the operation of a rotor arm which is coupled to a worm housing driven through a free-wheel mechanism by a motor fitted with an electromagnetic brake.

As the rotor arm approaches an inlet port, a cam mechanism fitted to the housing snaps it forward into position, the free-wheel mechanism being disengaged by the drive motor. The circuit to the valve motor is, at the same time, broken by a valve switch.

To co-ordinate the 54-way recorder with the 54-way selector valve in all of its sampling positions there is a 54-way selector switch

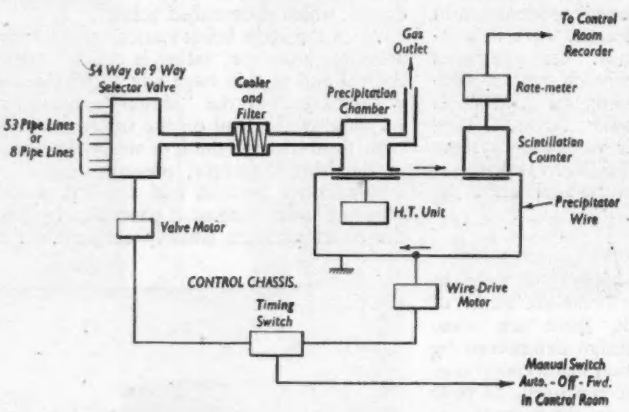


Fig. 21—Block diagram of fifty-four or nine-way gas sampling system for burst slug detection

consisting of a 6-way and a 9-way switch driven from the worm housing of the selector valve and containing a magslip. This magslip operates the repeater of a 54-way dial indicator which is installed in the control room to give remote indication of the valve rotor arm position.

The recording instrument is a modified form of Elliott self-balancing potentiometer recorder, the carriage of which has nine pens, each of which is controlled by the 9-way switch mentioned above. There are six positions of the carriage, and they are controlled by the 6-way switch. The 6-way and 9-way switches therefore keep the recorder in step with the 54-way selector valve : as each sampling position is chosen in turn by the selector, the appropriate pen is brought into operation.

A monitoring system is installed to determine whether the recorder is operating correctly in step with the selector valve. Signals are fed from the recorder channel selector to fifty-four neon lamps installed on the circumference of a circular dial in the control room. A centrally pivoted pointer on the same dial is driven by a magslip repeater in circuit with the magslip transmitter on the selector valve and therefore indicates the rotor arm position. As long as the illuminated neon lamp coincides with the pointer indication the system is shown to be in order. Some of these instruments can be seen in Fig. 18 ; a row of dial indicators is mounted between two rows of recorders on the wall panel behind the operator who is seated at the central control desk.

The precipitator unit is illustrated in Fig. 22. It consists of two main parts : the body, which is in the form of a cylindrical casting housing the precipitation chamber and the scintillation counter ; and a stand which supports the body and contains a control chassis, h.t. unit, rate-meter and indicator panel. The precipitation wire passes around driving and idling pulleys of "Tufnol" to form a motor-driven loop inside the precipitation chamber. The h.t. unit maintains a potential difference of 5kV between an outer electrode in the chamber and the central precipitator wire which is earthed. When gas is admitted to the chamber the electric field between the outer electrode and the wire causes those radioactive atoms of gas which decay into a solid state to be deposited on the wire. At the end of the 28-second sampling period this part of the wire is moved to the scintillation counter and the selector valve moves to the next inlet port.

The radioactive solids deposited on the precipitator wire decay again by emitting beta particles which pass through a phosphor cylinder mounted concentric with the wire. Light flashes produced during this decay are detected by a photo-multiplier which is in contact with the phosphor in the cooling tube. The rate-meter integrates the number of light flashes over the measuring period of twenty-eight seconds and the result is shown on the recorder in the control room.

The electromagnetically-braked motor driving the precipitator wire loop over pulleys is mounted on top of the precipitation chamber (Fig. 22). In the upper part of the stand is the control chassis housing

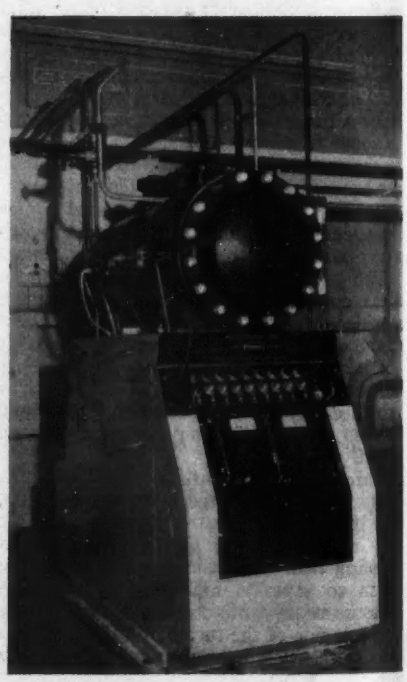


Fig. 22—One of the precipitator units in the sampling system for detecting burst slugs in No. 1 reactor

the operating circuits for the wire-drive motor and the gas valve motor and the warning circuits which give indication of failures within the gas sampling plant. Immediately below the control chassis is the rate-meter panel. A sloping panel on the rear of the stand carries the e.h.t. unit, a gas pressure gauge and a gas temperature gauge which operates a warning circuit.

There is a precipitator unit for each of the eight zones into which the fuel channels are divided for leak detection. In addition, there are separate chambers which provide continuous monitoring near the top and bottom of the reactor to give a continuous reading of the gross radioactivity in the coolant. They provide a remedy for the "blind spot" which would otherwise exist in the system if a leak occurred in a particular channel immediately after it had been sampled, when it could not be detected until the next sampling, twenty-seven minutes later.

The control and warning circuits for each precipitator are completed through a switchboard; any faults that may develop are indicated visually on the switchboard and on group warning alarms in the control room.

Feed Water System

The feed water system follows standard power station practice with two main differences. First, for reasons associated with reactor cooling, as explained in the previous article, the steam cycle is non-feed-heating. Secondly, refinements are introduced into the system as a precaution against corrosion of the heat exchanger tubes, which would not be readily accessible for maintenance. The permissible oxygen content of the feed water is therefore limited to 5 p.p.m., and this condition is maintained with the help of Hick Hargreaves de-aerators from which the de-aerated water is taken by an extraction pump, passed through feed coolers and then discharged to the boiler feed pump. Part of the de-aerated water is, however, returned by the extraction pump to the de-aerator storage tank. Make-up feed water comes from Wastwater and is subjected to demineralisation before being discharged into the hot drain tank. Thence the water is pumped as required through a heat exchanger and vapour condenser to a de-aerator and is discharged by an extraction pump to the suction branch of the boiler feed pump.

Pipework and Valves

The high-pressure and low-pressure steam mains from the heat exchanger superheater outlets to the steam receivers, from the receivers to the turbine steam chest inlet flanges and to the steam dumping valve inlet flanges are of carbon steel, mainly of tube, 16in outside diameter and ½in wall thickness, with intermediate joints butt welded by the metal arc process. These butt welds were examined by gamma-graph. At terminal points the Aiton "Corwel" seal weld joint was used. From the outlet flanges of the steam dumping valves to the dump condensers the piping is fabricated from m.s. plate; bellows expansion joints made from ⅛in thick stainless steel plate are fitted to take the thermal expansion. High-pressure feed piping from the discharge flanges of the feed pumps to the terminal flanges at the heat exchangers is also of carbon steel tube and again the joints are butt welded and gamma-graphed. The pipework mentioned above—together with an extensive system of low-pressure condensate piping, auxiliary steam, station heating, CO_2 and high and low-pressure piping—was supplied and erected by Aiton and Co., Ltd.

Among the interesting valves installed at Calder Hall are the Blakeborough 54in diameter power-operated wedge gate valves supplied for the reactor coolant system. These valves (Fig. 24) are mounted on the hot and cold CO_2 ducts between the pressure vessels and their associated heat exchangers; there are sixteen in the "A" station. Half the valves are designed for vertical mounting, and half for horizontal mounting in vertical ducts. They are of outside screw construction, with cast steel casing and gate, "Monel" metal seat and face rings, and aluminium bronze stem and tubular rising spindle. The operating gear is electric-motor-driven, capable of opening or closing the valve in two-and-a-quarter minutes. Remote control and remote "open-shut" indication are provided.

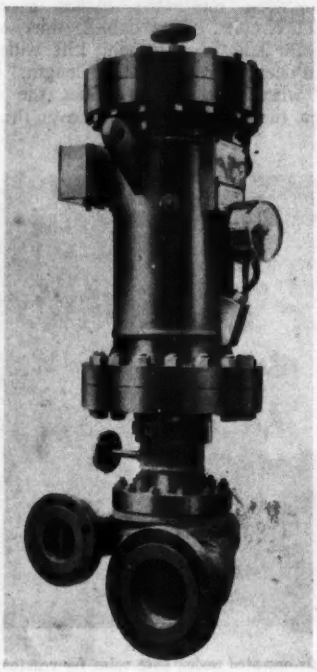


Fig. 23—Glandless pump for circulating water through the heat-exchanger circuits. The pump and electric motor are housed in a pressure shell to prevent leakage to atmosphere

Because of the possibility of radioactive contamination special precautions were taken in the design and manufacture of these valves to avoid leakage in service. The testing procedure included radiographic examination of all pressure castings; hydrostatic tests on casing and gate; seating tests under compressed air, and operating and tightness tests under full working temperature conditions of 700 deg. Fah.

Glandless Pumps

Thirty-four glandless pumps developed by Hayward Tyler and Co., Ltd., were supplied for circulating the water through the heat exchanger sections. These pumps were developed from a design which was described and illustrated in The Engineer, June 3, 1955, page 774. They are electrically driven, the pump impeller and motor being vertically mounted and enclosed in a pressure shell (Fig. 23) to prevent leakage to atmosphere; no rotating seals are used. The complete pump unit is mounted vertically and supported by the suction and discharge flanges, no base-plate being required. When the pump is at rest the pressures on both ends of the shaft are equal and, therefore, there is no thrust bearing drag to be overcome during starting. Both thrust and journal bearings are of the tilting-pad design using plastics for the disc (thrust) and sleeves (journal) running against stainless steel pads. These bearings are water-lubricated and are designed to require no maintenance during service.

Switchgear and Cabling

The main 11kV electrical circuits at Calder Hall power station are arranged so that the station can supply, as far as possible, the power requirements of the adjoining plant at Windscale. The switchgear, which is metal-clad horizontal-drawout equipment with oil-break circuit breakers, is installed in two switch houses. One of these is situated in the power station at Calder Hall and houses two 500MVA switchboards, each comprising three Reyrolle "B5T" circuit breaker panels (Fig. 25). The other is situated about 1000 yards from the power station in a substation at Windscale and houses a 750MVA switchboard comprising seven Reyrolle "A3T" circuit breaker panels which are divided into two three-panel sections. Each of the 500MVA switchboards and each section of the 750MVA switchboard controls (1) a 30MVA transformer connected to the C.E.A. 132kV grid, (2) a 23MW generator, and (3) an outgoing feeder to a nuclear pile through a 30MVA reactor. Controls for the four turbo-generators as well as tap change facilities for the four grid transformers are available from the main control room at Calder Hall. There is also a local control board at Windscale for all switchgear at that substation.

The power station main control board is of corridor construction, with instruments, controls and a superimposed line diagram on the front panels, and with the relay cubicles at the rear. This board accommodates the control, instrumentation, and automatic voltage regulation equipment for all four generators—two on standard controls and two on a 50V d.c. direct-wire "miniaturised" control. The standard controls for the Calder reactor feeders and the Calder grid transformer feeders are also included on this control board together with 50V d.c. "miniaturised" tap-change controls for the grid transformer feeders at Windscale. Each circuit is equipped with a 50V d.c. alarms facia and associated relay equipment. A general-purposes cubicle is situated in the centre of the control suite to house the general-purposes alarms and the normal/emergency lighting changeover facilities. There are two synchronising cubicles with "miniaturised" equipment situated one at each end of the control board, either of which may be used for synchronising the generator or grid transformer circuits.

The control room engineer's desk is of light oak (Plate 1, facing page 464, October 5, 1956), with metal inserts accommodating the controls for the four generators and the tap-change equipment for the four grid transformers, duplicated from the main control board. The desk has the usual facilities of drawer space, writing desk, and G.P.O. and operational telephones. At Windscale the control board is also of corridor construction with normal synchronising facilities, and is for the control of the 750MVA switchgear at the Windscale substation, which is normally unmanned. For centralisation of the main controls, however, the two generator panels at this station and the tap-change equipment for the two grid transformers connected to this station are

normally controlled over the 50V "miniaturised" system from the main control board at Calder Hall referred to above.

Two cubicles are incorporated at the rear of both the power station and the substation control boards to house the relays associated with the busbar zone protection of the metal-clad switchboards. The protection is a high-impedance system operating on a differential current balance principle and gives both phase-fault and earth-fault protection.

All the 11kV generator switchgear, together with the associated control and ancillary equipment was supplied by A. Reyrolle and Co., Ltd. The installation included the 1500A main and the 60A generator drain resistors, and the single-phase "ASPT" metal-clad switchgear with oil-break circuit breakers for neutral earthing, together with the associated generator pit copperwork and case type current transformers for metering and protective services.

Supplies for the reactor and turbine room auxiliaries are at two voltages, 3·3kV and 415V, the switchgear for which was supplied by the English Electric Company, Ltd. Air-break switchgear was used at both voltages. The 415V gear is "OB3" equipment with a maximum current rating of 1600A; the 3·3kV gear is "OB33L" equipment and, for this installation, has a maximum current rating of 800A and a fault rating of 150MVA.

For the turbine room and the four generators there are two 3·3kV switchboards with fourteen and fifteen panels respectively, as well as two eight-panel 415V switchboards. There is also a thirteen-panel 3·3kV switchboard controlling the five circulating water pumps in the pump house. For the reactors there are two thirteen-panel 415V switchboards, one for each reactor house. Among the circuits that they supply are those for the generator sets feeding the reactor control rods.

Cables for the power, control and telecommunication circuits at Calder Hall power station were supplied by British Insulated Callender's Cables, Ltd. Two of the four turbo-generators at Calder Hall "A" are connected by 11kV single-core cables laid in trefoil formation to two 500MVA switchboards and thence to two 30MVA transformers installed in the new Calder transformer station of the C.E.A., a total cable run of 240 yards. Similar cables connect these two switchboards via reactors to 350MVA switchboards, housed in each of the reactor buildings; the 350MVA switchboards are interconnected by a 250-yard run of this cable.

The output from the other two turbo-generators is fed by eighteen 11kV single-core cables laid in six trefoil groups to a 750MVA switchboard in a new switch house near Windscale works. From this switchgear, 11kV cables run to two transformers at the C.E.A. Windscale transforming station. This main cable route, 1100 yards long, between Calder and Windscale, is also shared by eighteen multi-core cables used for control circuits. The cables, thirty-six in all, were laid in a trench, 15ft wide and 3ft 6in deep, for most of their length. However, where the route crosses the River Calder, the cables are carried over the river by a steel bridge, 250ft in length, built specifically for this purpose.

Originally, Windscale works derived its power from the Grid and, for this purpose, the B.I.C.C. group of companies had built the 132kV line from Roosecote power station, near Barrow, and supplied and installed 600 yards of 132kV gas-filled, single-core cable for the termination of two of the overhead line circuits at the Windscale transforming station. Since Windscale is to take power from Calder Hall, the B.I.C.C. contract included cutting the original 11kV feeders from the transforming station to the works and rerouting them via two reactors into the new 750MVA switch house.

The power circuits described above use three 11kV, 1·0 square inch conductor, paper insulated, lead-alloy-sheathed and served single-core cables per phase, and were cleated using non-magnetic cleats of special design. Three kinds of cleats were used: single, trefoil and, for use on vertical runs, independent trefoil. Horizontal runs of cable were cleated at intervals of 6ft 6in. This spacing is rather wider than the usual practice but was found by B.I.C.C. to be the optimum spacing for use at the Capenhurst Atomic Energy Plant and it has now been adopted as standard by the U.K.A.E.A. The cables from the alternator are terminated by right-angle sealing ends fixed to the wall of each alternator terminal cubicle.

The control circuits installed by B.I.C.C. used multi-cored, paper-insulated, lead or lead alloy sheathed, wire-armoured and served cables. Those provided were 15-pair and 75-pair 20 lb per mile conductor telephone cables and 4, 7, 14, 19 and 37-core 7/0·029 conductor cables. For these circuits, numerous distribution boxes and fittings were supplied and installed, including 900-, 600- and 360-way "marshalling kiosks" which were specially designed for this installation.

In conjunction with Strachan and Henshaw, Ltd., the main contractor for the reactor fuel element charging and discharging machinery, new B.I.C.C. cables were developed. These cables are designed to withstand the high temperatures and radiation encountered by the grabs used to handle the reactor fuel rods, without failure or loss of electrical performance. The first kind of cable, of which more than forty lengths are being supplied, contains six 19/0·0076 nickel-plated copper P.T.F.E. insulated cores laid around a central 110-ton quality steel strand and is used for the electrical control of the reactor charging and discharging grabs. The second kind of cable which is being installed experimentally at Calder Hall incorporates a flexible central duct in addition to the electric wires, and enables electro-pneumatic control to be achieved with the use of only one flexible cable.

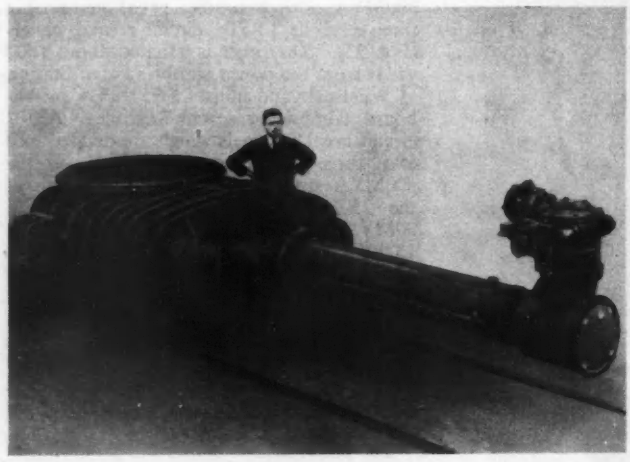
Two sets of rectifier equipment, for supplying the d.c. fan motors associated with the reactor cooling system, were supplied by the British Thomson-Houston Company, Ltd., to the order of Whipp and Bourne, Ltd. Each set consists of two pumpless steel-tank mercury rectifiers and one rectifier transformer with 33-position on-load tap-change gear. The rating of both equipments is 233/400/566kW, 200/240/335V, 1667/1667/1667A, two-wire d.c., six-phase, and they work on a 415V, three-phase, 50 c/s supply.

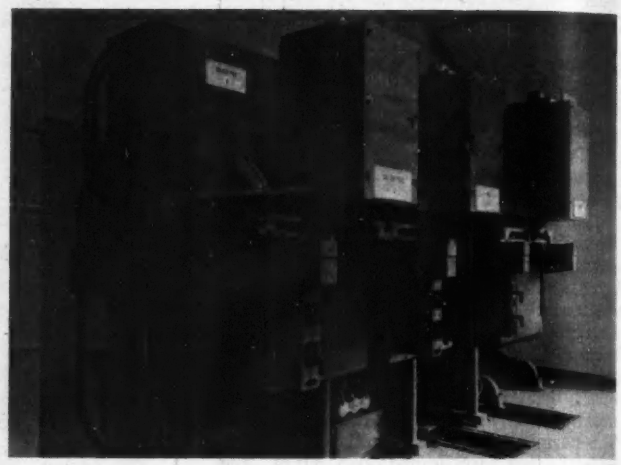
For safeguarding essential supplies to reactor auxiliaries there are two large stand-by batteries, supplied by Chloride Batteries, Ltd., of Clifton Junction, Swinton, Manchester. Each consists of 120 "OFW.13" Chloride Planté cells with a capacity of 1950Ah at the ten-hour rate of discharge assembled in lead-lined wood boxes.

The batteries are each connected in parallel with a twin-bulb 400kW mercury-arc rectifier set at 270V. Normally this arrangement provides a floating trickle charge across the 120 cells of 2·25V per cell.

The pumps, fans, instrumentation and emergency lighting for each reactor are normally supplied by the rectifiers, but should their output fail, the batteries automatically take over.

Each battery is designed to supply 1200A





Figs. 24 and 25—(Left) 54in diameter cast steel electrically-operated wedge gate valve for reactor coolant service (Right)—The 11kV generator switchgear at Calder Hall consists of 500MVA metalclad horizontal drawout switchgear with oil break circuit breakers

for half an hour. After an emergency discharge, the rectifier is capable of quick-charging its battery and supplying the reactor's auxiliary services at the same time.

Contractors

The main contractors and some of the sub-contractors are listed below.

Building and civil engineering work, Taylor Woodrow Construction, Ltd. Structural steelwork, Alexander Findlay and Co., Ltd.

Reactor pressure vessels, Whessoe, Ltd. Steel for reactor pressure vessels, Consett Iron and Steel Company, Ltd. Survey and inspection of pressure plant, including reactor vessel and heat exchangers, Lloyd's Register of Shipping, Land Division.

Steel plates for thermal shield, English Steel Corporation, Ltd., and Steel Company of Wales, Ltd. Graphite blocks, British Acheson Electrodes, Ltd. Services concerned with reactor thermal shielding, graphite laying, burst cartridge detection, ventilation and plant erection, Matthew Hall and Co., Ltd. Thermal insulation of reactor vessel with Darlington 85 per cent Magnesia and Meta Dextramite, The Darlington Insulation Company, Ltd.

Charge and discharge machines and equipment, Strachan and Henshaw, Ltd.

Reactor control rods, frequency converter sets and associated plant, Metropolitan-Vickers Electrical Company, Ltd.

Burst slug detection system, Plessey Nucleonics, Ltd.

Heat exchangers, Babcock and Wilcox, Ltd. Steel for heat exchanger shells, Colvilles, Ltd. Heat exchanger mountings and parallel slide valves for steam and feed lines, Dewrance and Co., Ltd. Thermal insulation of shell, pipework, &c., The Darlington Insulation Company, Ltd. Heat exchanger lift, Costain-John Brown, Ltd. Preheating and stress relieving the shell; Electric Furnace Company, Ltd. Glandless pumps, Hayward Tyler, Ltd. E.r.w. tube for heat exchangers; and 16in steel water pipes, Stewarts and Lloyds.

Coolant ducting, Robert Jenkins and Co., Ltd. 54in valves for gas circuit, J. Blakeborough and Sons, Ltd. Liquid carbon dioxide, Carbon Dioxide Company.

Steam turbo-generators, condensers, "dump" condensers, carbon dioxide insulators, C. A. Parsons and Co., Ltd. Desuperheater control cubicles, oil purifiers, valves, Hopkinsons, Ltd.

Station pipework, Aiton and Co., Ltd.

Stainless steel tubing, Accles and Pollock, Ltd.

Feed water regulators, G. and J. Weir, Ltd.

11kV switchgear and associated control and ancillary equipment, A. Reyrolle and Co., Ltd.

3·3kV and 415V switchgear, English Electric Company, Ltd.

Power telephone and control cables, British Insulated Callender's Cables, Ltd.

Rectifiers for d.c. fan motors, British Thomson-Houston Company, Ltd., to the order of Whipp and Bourne, Ltd.

Stand-by batteries for reactor auxiliaries, Chloride Batteries, Ltd.

Recorders for measurement and control of radioactivity, reactor power level, pH, B.Th.U. and temperature and flow recorders and draught gauges, George Kent, Ltd.

Provision of instrument panel, desk and other control room furniture and instrument installation in the reactor control rooms, New Western (Engineering), Ltd.

Electrical installation work, N. G. Bailey and Co., Ltd.

One 60-ton, four-motor travelling crane of 78ft span in the main turbine room and four 15-ton, three-motor cranes of 56ft 4in span in the blower houses, The Wharton Crane and Hoist Company, Ltd.

Drifting Tools.—When it is required to cut out a shape in thick metal it is common practice to drill a series of holes and cut out the thin intervening partitions of metal with a chisel, when band saws or flame cutting equipment are not available. A drifting tool of Swiss manufacture has been developed to speed and facilitate this method of cutting out, and is now marketed in this country by Trend Industrial Equipment, Ltd., 5, The Ridgeway, Stanmore, Middlesex. These "Holex" tools, as they are known, are made in sets of five, different sizes being available for varying thicknesses and classes of material. The tools are of appropriate length and are cylindrical in shape to fit the holes with about 0·001in clearance. A wedge-shaped cutting edge projecting from the side of the tool cuts the partition of metal between two holes away as the tool is hammered or pressed down one of the holes. The tools are made with base diameters from $\frac{1}{16}$in to $\frac{7}{16}$in and from $2\frac{1}{2}$in to 4in long.

A.C. and D.C. Conduction Pumps for Liquid Metals

By L. R. BLAKE, Ph.D., B.Sc., A.M.I.E.E.*

No. I

An examination is made and the chief design features established of the d.c. conduction pump and of the mains-frequency and low-frequency a.c. conduction pump, including types with combined low-voltage transformer. Special consideration is given to their behaviour at high output powers with liquids such as bismuth. Performance figures of typical designs are given and the relative merits of the different types of conduction pump are outlined. It is suggested that the low-frequency a.c. conduction pump is a useful alternative to the d.c. conduction pump and homopolar generator.

ELECTROMAGNETIC pumps utilise the good electrical conductivity of liquid metals to establish electromagnetic forces directly in the liquid itself, so avoiding the need for mechanical impellers. There are many kinds of electromagnetic pump, the more important being the d.c. pump (the principle of operation of which is shown in Fig. 1), the a.c. conduction pump, the spiral induction pump ("Sip"), the annular linear induction pump ("Alip"), and the flat linear induction pump ("Flip").

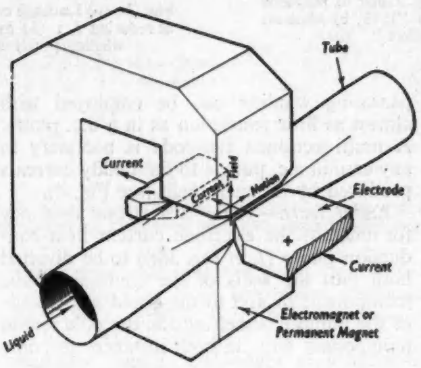


Fig. 1—Principles of d.c. conduction pump

The relative merits and fields of application of these different pumps have been given elsewhere,[1] but briefly the situation is as follows. Induction pumps are generally the most convenient but are rarely suitable for the high density, viscosity and resistivity liquid metals like mercury, lead or bismuth; they are mainly used with liquids like sodium, sodium-potassium and lithium, the "Sip" effectively dealing with low-flow, high-pressure applications, and being particularly useful at small output power, the "Alip" and "Flip" being useful in a wide range of outputs from 20 to 10,000 g.p.m. and 10 lb to 100 lb per square inch.

Conduction pumps can handle any liquid metal, though with varying efficiency. The main disadvantage of the d.c. conduction pump is its inconvenient electrical supply requirements—thousands of amperes at a potential near 1V; for example, a 2000 g.p.m., 75 lb per square inch pump for bismuth requires 100,000A at 2·5V. About the only efficient supply at this voltage is the homopolar generator with liquid metal brushes. Metal rectifiers are sometimes more practicable in small pumps, but they are invariably very large and expensive in comparison with the pump itself; for example, a pump costing £250 might require rectifier equipment of £2000. Thus, in small pumps, there is a strong incentive to use the a.c. conduction pump. This is cheaper and has no supply difficulties, but it is usually less efficient than the equivalent d.c. pump, has a poor power factor and is sometimes noisy. The efficiency of the a.c. conduction pump rises to a maximum at a certain power size (about 2 h.p. output at 50 c/s) and thereafter falls; the power factor progressively worsens with increase in size. Thus, it compares very badly in performance with d.c. pumps in large sizes, unless the supply frequency is lowered. This improves the power factor and efficiency and raises the upper limit of useful pump size, but a low-frequency generator is then necessary. A more detailed picture of the suitability of different kinds of pump for use at different output power levels is given later.

In a previous paper,[1] the design features and relative merits of induction and conduction pumps were deduced, but, of the conduction pumps, the d.c. pump received most consideration and insufficient attention was paid to comparing a.c. and d.c. conduction pumps. The a.c. conduction pump will now be examined in greater detail; different kinds will be compared, and the main design features established. The value of low-frequency operation will be questioned and, in the range of pump power where d.c. and a.c. pumps are most competitive, detailed designs of both will be made to assist comparisons.

General Design Considerations

"*Armature-Reaction*" *Effect.*—"Armature-reaction" effect is distortion of the gap field due to the magnetic effects of the current in the liquid; this in turn causes distortion of the current density distribution over the pole and electrode region (see Fig. 2), since the voltage between the electrodes

$$V = Hbv\,10^{-8} + \rho Jb = \text{constant} \quad . \quad . \quad (1)$$

the symbols being defined in Fig. 2.

Thus, as H varies with position in the flow direction, J does also; where H is high, J is low and vice versa. This distortion of J and H can lead to a marked reduction of the pump pressure and an increase in the pump losses. [1, 2]

Field distortion effects can be virtually eliminated by a compensating winding, as in the case of d.c. rotary machines; this is simply accomplished in the pump by returning the current which flows in the liquid and the tube walls through the pole, either as a pole face winding or as a flat sheet, preferably on both sides of the tube, as shown in Fig. 2(*b*) and (*c*). The current distribution in the compensating winding should match as closely as possible that of current in the liquid and tube, being proportional to the parent current and as close to it as possible.

A compensating winding is not necessary if the maximum field in the gap produced by

* Formerly with Research Laboratory, The British Thomson-Houston Company, Ltd., Rugby.

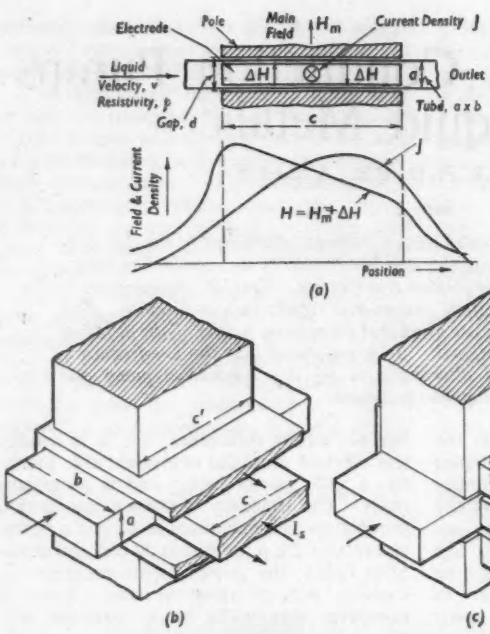
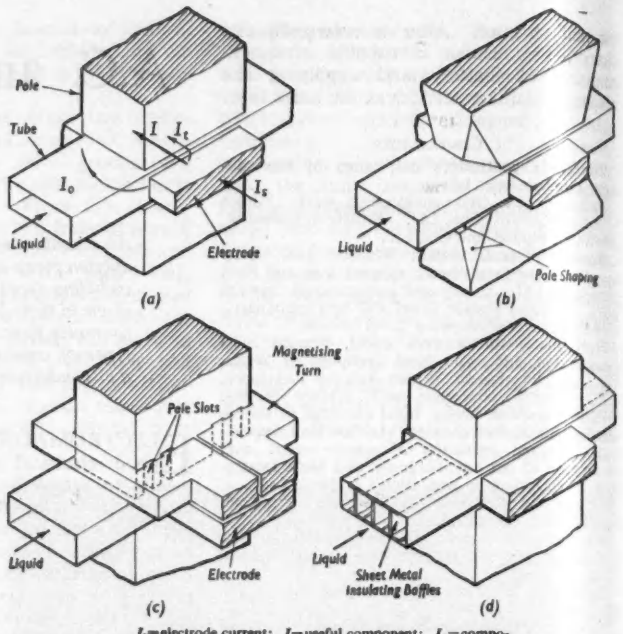


Fig. 2.—(*a*) Distortion of field *H* and current density *J* due to magnetic effects of electrode current (" armature-reaction effect "); (*b*, *c*) Methods of eliminating " armature-reaction effect "



I_s=electrode current; I=useful component; I_o=component in liquid outside pole; I_t=component in tube wall.

Fig. 3—(*a*) Leakage currents I_o and I_t in conduction pumps; (*b*, *c*, *d*) Methods of reducing I_o: (*b*) by pole shaping; (*c*) by field grading using a pole face winding; (*d*) by insulating baffles in tube at inlet and outlet

the current is appreciably less than the main field and when vc/ρ is low. The liquids of most interest with conduction pumps are, as already mentioned, those like mercury or bismuth; with these fluids the mean velocity v must be kept low to reduce hydraulic friction, since the density and viscosity are high; thus, as the resistivity is high also the ratio v/ρ is low in comparison with liquids like sodium. The controlling factors are H_i/H_m and $\beta = 2\pi vc/10^9\rho$, see reference [1], where H_i is the maximum field which would be produced in the gap by the electrode current flowing in the liquid and tube wall; it is given approximately by $H_i = 4\pi I_s/20d$, where I_s is the electrode current. For a self-excited, uncompensated pump it would be normal with a.c. excitation to employ a half or 1½ turn effective winding; if a 1½ turn winding is used this leads to a value of H_i/H_m of 0·33. Under these conditions β has to have the value 0·5 for the pressure to be reduced by 5 per cent and the losses to be increased by 8 per cent, as given by equations (65) and (66) of ref. [1], which incidentally give pessimistic results. For bismuth this would mean that a compensating winding becomes desirable with velocities exceeding 560cm/sec and c=18cm. With a ratio $c : b : a$ of 4 : 2 : 1, this corresponds to a pump of channel size 9×4·5cm and a flow of 300 g.p.m. With sodium, on the other hand, compensation is desirable at a velocity of 330cm/sec and c=2·4cm, which with a similar channel geometry corresponds to a 1·2×0·6cm channel and 3·2 g.p.m.

These figures roughly indicate the size of pump and the fluid flow rate at which compensation becomes desirable: it is evident that compension is much more necessary with sodium than bismuth; with general purpose pumps, suitable for use with different liquid metals, only with the smallest pumps can a compensating winding be omitted. In a.c. pumps, however, they must be employed with caution because of eddy currents which are induced within them; in practice, provided that the electrode circuit consists of a number of parallel paths, as in Figs. 4(*b*) and 7, these eddy losses can be restricted and a compensating winding can be employed with almost as little restriction as in a d.c. pump. A multi-sectioned electrode is necessary in any case in a.c. pumps to limit eddy currents produced by the main field (see Fig. 4).

End Effects.—There is a strong tendency for much of the electrode current in a conduction pump (I_s in Fig. 3(*a*)) to be diverted both into the walls of the containing tube (component I_t) and to the liquid at the ends of the pump channel outside the pole region (component I_o); in both instances the only restriction to current flow is ohmic resistance, unlike within the pole region where the induced voltage or back e.m.f. due to motion of the liquid in the magnetic field also restricts current flow (see equation (1)). To reduce, and at the same time make useful, the current at the ends, it is desirable to grade the field to match the natural fringing of the current density. This can be done by pole shaping, as in Fig. 3(*b*), or by passing the magnetising turns through the pole, as in Fig. 3(*c*), or the two methods can be combined. Some form of field grading is always desirable, though it can be provided in some instances by the natural fringing of the pole field. It is particularly important to utilise to the full every line of magnetic flux; shaping the pole in the relatively elaborate manner of Figs. 3(*b*) and (*c*) can be well worth while, therefore, particularly in a.c. pumps, when apparent power (kVA) is associated with flux, as well as increased core size, and consequently winding and pump size and pump losses.

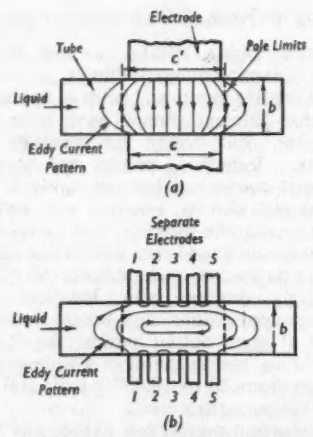


Fig. 4—Use of separate electrodes with opposite pairs connected to separate supplies to reduce eddy-currents in liquid and electrodes

An alternative possibility to reduce end currents is to insert insulating baffles in the tube outside the pole region; this can be done using sheet metal, as shown in Fig. 3(*d*). This arrangement is fairly complicated, however, and leads to additional hydraulic losses; efficient field grading would appear in general to be the more elegant solution.

Busbar and Electrodes.—Fig. 4(*a*) shows a section of pump tube and electrode, a typical arrangement for a d.c. pump. It is readily appreciated that under a.c. conditions the main alternating flux induces currents in the liquid as indicated by the arrowed lines, and the fringing flux induces currents in the electrodes and busbars themselves. These induced currents are very large, but they can be substantially reduced by dividing the electrode into a number of sections and connecting opposite pairs to different isolated windings of the supply transformer. Then the general pattern of the eddy currents in the liquid and busbars is substantially altered, and the losses produced by them are appreciably reduced. An estimate of the relative eddy losses involved in the two arrangements of Fig. 4(*a*) and (*b*) is somewhat involved, but as a rough guide, with bismuth and a channel geometry $a : b : c$ of 1 : 2 : 4, the eddy losses are about five to ten times as great with arrangement (*a*) as with (*b*). It depends on the ratio H/I_s adopted and the size of the pump whether the large losses associated with solid electrodes are acceptable, but in general solid electrodes are permissible only in the smallest pump sizes.

Magnet Circuit and Winding.—A series winding is generally the most suitable arrangement to employ; this simply involves wrapping the busbar to the tube electrodes a few times around the pole, which leads to a self-supporting coil requiring the minimum of voltage insulation. The series

winding is a natural choice since it does not increase the current requirement, which is already inconveniently high and, in a.c. pumps, it ensures that the field and current density are substantially in phase. No noticeably different characteristics are produced by shunt, series or compound windings as in rotary d.c. machines, since the induced voltage due to motion in the field is low and comparable with the ohmic voltage drop; thus, there is little incentive with self-excited arrangements to use other than a series winding. Separate excitation also has little to offer except that the pump can be controlled by its field which, in large machines, needs a relatively low power. Separate excitation, however, has the disadvantages of overheating of the pump when the field is zero and the current is maximum and, with a separately-excited winding operated from a higher, more convenient voltage source, there are considerable insulation difficulties, particularly when the liquid is hot and radioactive. In d.c. pumps, a permanent magnet system is an alternative but the pump is then larger and appreciably more expensive; it is practical in certain instances in small pumps but is scarcely worth considering in large pumps.

Assuming that the preferable arrangement is a d.c. pump with series winding, as many turns as possible are normally desirable in order that the field may be kept high and the current requirements low. However, the number of turns are limited by the maximum field which can conveniently be provided in the gap, which is closely related to the saturation flux density of iron. Another limitation is due to the fact that, if the induced voltage term $E=Hbv\ 10^{-8}$ is made too large in comparison with the ohmic drop term ρJb, much of the electrode current is diverted uselessly to the ends and into the tube walls: this makes the pump pressure show a maximum value as the turns are increased or the field is raised, keeping the current constant.[1, 10] A further disadvantage of using many turns in the series winding is that the pump size then increases. Normally in d.c. pumps up to three or four turns are useful in small pumps of around 5 g.p.m. and a single turn winding is employed in large pumps.

In the a.c. conduction pump a further consideration intrudes in the number of series magnetising turns (or alternatively the ratio H/I_s or ϕ/I_s) to employ. The larger the turns or ratio ϕ/I_s, the larger is the pump, as in the d.c. case, but in addition the larger is the input apparent power and the lower is the power factor. Thus, in a.c. conduction pumps a single-turn exciting winding would be the natural choice with any size of pump, particularly since the larger supply current which this entails is no longer inconvenient as in the d.c. case.

The location of the magnetising winding is also of considerable importance. If the winding is wound round the poles near the gap the leakage factor or ratio of total flux to useful flux can be kept to a figure usually near 2; if the winding embraces the yoke member of the core furthest from the gap the leakage factor can exceed 5. Thus, the core volume can be more than doubled and the mean winding length substantially increased, and this can lead to doubling or trebling the size of the pump; with the a.c. pump this means also that the input apparent power is at least doubled and the power factor halved. Thus, in both d.c. and a.c. pumps, but particularly with the latter, it is essential to adopt an arrangement which keeps leakage flux to an absolute minimum. This normally implies a series winding as small as possible, surrounding the magnet gap and positioned as close as possible to it. Similarly, in the a.c. pump, the supply busbars should be close together, and if possible interleaved to keep the busbar reactance as low as is practicable.

Generally the most convenient magnetic circuit is a single-C core as this gives rise to less leakage flux than the double-C or shell-type core; the weight of a single-C core is somewhat greater, however.

Channel and Magnet Geometry.—The relative proportions $a:b:c$ of a conduction pump closely affect the performance. Generally a large value of c/b is desirable to improve the efficiency but this leads to increased pump weight and, if taken too far, excessive flux fringing; a large value of b/a is desirable to keep the supply current low, but this also increases the size of the pump. The absolute dimensions of the channel, particularly the product ab, the tube cross-section, is controlled mainly by the hydraulic losses, which become excessive if ab is too small, but there is another limit for, in a normally proportioned pump, a small value of ab can lead to excessive copper current densities, and the inability to dissipate these losses. Other details of the change in pump performance with pump design features are given in Blake's Table II.[1]

In the case of the a.c. conduction pump there is an additional consideration. It will be shown that the power factor of the pump is inversely proportional to c^2, which is another incentive to keep low the absolute value of c and its value relative to a and b. Thus in the a.c. pump low power factor high efficiency and small size are all in conflict, just as in the d.c. pump, low supply current, high efficiency and small size are mutually in conflict.

Another factor which influences the pump geometry is the ratio of pump pressure to pump flow. Since the pump pressure is given by

$$p=JHc/10.\ \text{dynes/cm}^2 \quad . \quad . \quad . \quad (2)$$

then, if the current density J and the field H are near their limiting values, the only way to increase the pressure is to increase the value of c. Since the tube section ab is already well defined by the flow, it is evident that a high-pressure, low-flow pump will tend to have a large value of c in relation to a and b. The ratio of c/a and c/b cannot be increased without limit, however, so in practice the maximum pressure achievable depends on the flow rating of the pump, the larger the flow the larger the pressure achievable. This restriction on the maximum pressure-to-flow ratio can be avoided by a complete departure from the standard arrangement so far discussed, employing instead a spiral or helical channel, an arrangement which has the additional merit of being economical in electrode current, I_s.

In Fig. 5 we show two examples of series-excited, helical-channel conduction pumps; in Fig. 5(*a*) is a d.c. pump and Fig. 5(*b*) an a.c. pump. In the d.c. pump the liquid flows circumferentially in the annular channel, guided by vanes with a right-hand screw on the left-hand side, and with a left-hand screw on the right-hand side. The field is radial and the current axial, so Fleming's left-hand rule is obeyed. There are two hollow cylindrical input busbars, the inner joining the right-hand side of the annular tube. The current circuit is axial along the tube, across the guide vanes to the ring electrode at the left-hand side, which is joined to the hollow copper cylinder between the pole and the tube; current in this cylinder provides compensation for the circumferential magnetising effects of the current in the liquid. The copper cylinder is connected to a helical copper coil, which provides the magnetising winding, the other side of which joins a similar hollow copper cylinder between the right-hand pole and the annular tube; this connects to the outer input busbar. The magnetic circuit consists of an inner cylindrical core, usually of "Permendur," and a hollow cylindrical yoke and two ring poles, usually of low-carbon steel. A pump of this type has been made for bismuth with a nominal rating of 0·5 g.p.m. and 60 lb per square inch.

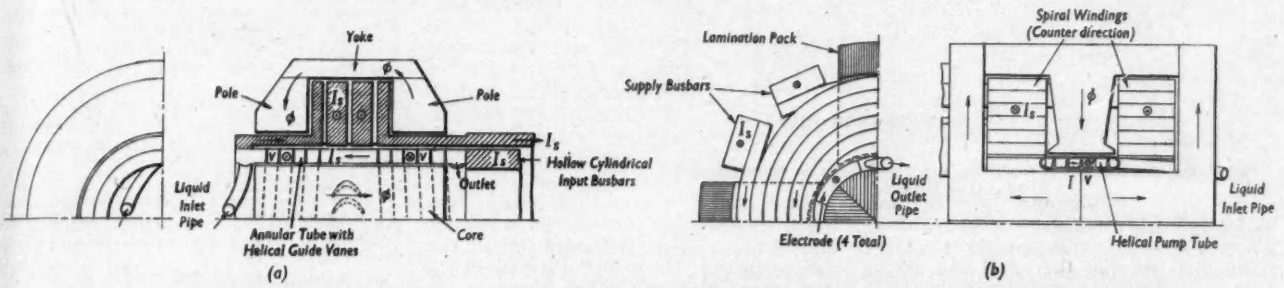


Fig. 5—Conduction pumps with helical channels. (*a*) A helical channel d.c. conduction pump with series magnetising and compensating windings (*b*) A helical channel a.c. conduction pump with series magnetising winding

Fig. 5(*b*) shows a helical conduction pump arranged for a.c. operation with an alternative winding arrangement. With a little more elaboration in routing one of the supply busbars nearer to the central pole and the pump channel this pump also is quite effectively compensated for armature reaction, though the magnetic circuit geometry and magnetising arrangements as shown are in any case such as to make small the circumferential magnetisation effects due to the axial component of the current. The a.c. and d.c. versions of the helical pump are competitive, as are the usual linear forms of a.c. and d.c. conduction pump.

Pump Materials.—The tube material depends on the liquid being pumped, it being common practice to use stainless steel with sodium and chrome-iron with bismuth:

much information on suitable materials for use with different liquids is given in *Liquid Metals Handbook*[3, 4] and *Reactor Handbook*.[5] It is desirable that the material be of the highest possible electrical resistivity to reduce wall currents, though not too high on the sides of the tube where the electrodes are attached. The Nimonic series of alloys are suitable for use with sodium and have resistivities of about 120 microhm-cm, but difficulties of welding them to the remainder of the pipework often make it desirable to avoid their use, employing instead the same materials as used elsewhere even though their properties are inferior. Stainless steel of 18/8 type is commonly used for sodium

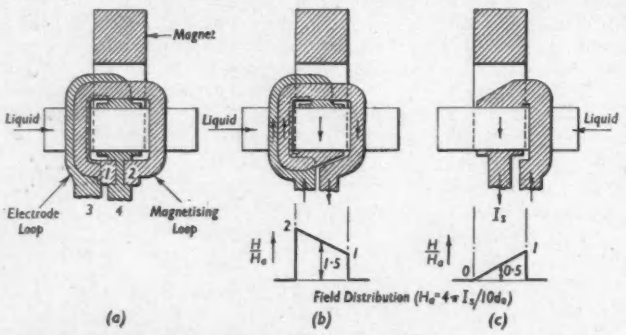


Fig. 6—Possible methods of connecting series winding in an uncompensated conduction pump

piping and has a resistivity at 20 deg. Cent of 72 microhm-cm ; at 500 deg. Cent. the resistivity is 108 microhm-cm, which is almost as high as Nimonic at the same temperature, since the temperature coefficient of Nimonic is low. The materials with the lower resistivity at room temperature usually have the higher temperature coefficient ; thus the difference between materials at high temperature is often not significant. This is true of the chrome-irons as well as the stainless steels, the high-chrome alloys having the larger resistivity but lower temperature coefficient, so that they differ but little at temperatures about 500 deg. Cent. Thus there is little objection to the low-chrome iron at these temperatures. However, low-chrome irons suffer large erosion at high temperature in air ; this must not be permitted, since the tube wall must of necessity be thin.

It is also desirable that the tube material be non-magnetic or have a low saturation flux density ; more accurately the sides of the tube parallel to the pole faces of a conduction pump are best magnetic and the sides joined to the electrodes should be non-magnetic. Austenitic stainless steels are non-magnetic, but martensitic and ferritic stainless steels, including chrome-iron stainless steels, are strongly ferromagnetic. If ferromagnetic steels are used for the tube the sides attached to the electrodes by-pass the flux across the pole and cause weakening of the field near the electrodes ; this must be allowed for in the design. Fortunately, in conduction pumps the value of flux density employed is usually high and the effective permeability of the material and amount of flux lost is fairly low.

Copper electrodes can be fixed to the tube wall by brazing, welding or casting. The use of a number of electrodes separately connected to the tube wall helps to reduce thermal stresses due to the differential thermal expansion of electrode and tube materials, which can lead to buckling of the tube wall. Brazing is usually unreliable and welding or casting on electrodes is preferable, the busbars being joined to the electrodes using a high-temperature brazing material. Liquid metal electrodes and liquid metal busbars have been suggested[9] and can be useful in certain circumstances : however, to keep flux leakage to a minimum it is best to keep the winding section to a minimum, close to and surrounding the gap ; therefore, copper is the natural choice of material. As the copper operates near the liquid temperature, it would suffer serious erosion in air at high temperature, 0·1in per year at 500 deg. Cent being a typical figure. This can be reduced by aluminium spraying of the copper or by operation in an inert atmosphere.

Useful insulation materials are mica, asbestos, glass and pure silica fibre, but the insulation levels in conduction pumps are very low and the natural oxide-coated surface is often sufficient.

The magnetic core material should be capable of operating at a high flux density with a moderate magnetising field. A high saturation flux density is the property of importance, particularly for the material for the pole pieces, and " Permendur " (a 50 per cent cobalt-iron alloy) is usually well worth while in this portion. Its saturation flux density is nearly 24 kilogauss and it can be operated at 18 to 20 kilogauss with a magnetising field of 10 to 40 oersteds ; the resistivity of " V-Permendur " is 26 microhm-cm. " Permendur " is useful in d.c. and a.c. pumps alike, being used, naturally, in laminated form in the latter case. The iron outside the winding region is not so critical and a low carbon steel is cheapest in d.c. pumps and a low silicon steel (2 to 4 per cent Si) is best in a.c. pumps ; 4 per cent silicon steel is to be preferred in 50 c/s a.c. applications because of its high resistivity, and low silicon steel in low-frequency applications, because of its better magnetic properties at high inductions. The operating flux density is best made as high as possible, particularly in the parts of the iron circuit near the gap ; the optimum flux density for d.c. pumps corresponds to an m.m.f. drop in the iron of 5 to 15 per cent of the total, but in a.c. pumps a lower flux density than this may be chosen to limit iron losses.

Series-Excited Uncompensated Conduction Pump

It has been shown that small pumps need no compensating winding to eliminate or reduce the magnetic effects of the current in the liquid. Methods of magnetising a core under these conditions will now be examined.

The basic winding of an uncompensated pump consists of a magnetising loop containing an integral number of turns and an electrode loop of a single turn embracing effectively a half of the pole area, as in Fig. 6(*a*). Assuming that the magnetising loop consists of one turn, it can be connected in series with the electrode loop in two different ways : with the free ends 1 and 4 joined together and the supply connected to 2 and 3, or 1 and 3 joined together and supplies to 2 and 4. These connections are indicated in Fig. 6(*b*) and (*c*). As the latter connection involves currents flowing in opposite directions, in bars 1 and 3, it is equivalent to joining the magnetising and electrode loops at the far side of the tube.

It is evident that connection (*b*) gives one and a half magnetising turns effectively and connection (*c*) one-half magnetising turn ; superimposed on the main field is the " armature-reaction " field causing increase of field at inlet and reduction at outlet. More than one turn of the magnetising loop gives rise to an effective number of turns of $2\frac{1}{2}$, $3\frac{1}{2}$, $4\frac{1}{2}$, and so on. In d.c. pumps the choice of the number of turns depends on the same considerations as in the compensated pump, one and a half turns or more being usual, for without compensation the pump is undoubtedly small when many turns become desirable. In a.c. pumps the choice is essentially between one-half turn and one and a half turns ; one-half turn is generally to be preferred since it leads to a better power factor and smaller pump size, though armature reaction effects are larger. Tests by Watt[6] on experimental models confirm this view.

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[10] Barnes, A. H., "D.C. Electromagnetic Pumps," *Nucleonics*, January, 1953, page 16.

(*To be continued*)

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.

AXLES

No. 24, Part 1 : 1956. Price 4s. This revised British Standard is part of a general revision of British Standards for railway materials.

It incorporates the requirements for carriage and wagon axles previously covered by specifications 3 and 3A, with minor amendments. The four separate specifications included are as follows : locomotive crank axles, solid forged ; locomotive straight axles ; locomotive straight axles (acid open hearth steel), and carriage and wagon axles.

Each specification includes requirements for the quality of the material, and the branding, heat treatment and the methods of testing are described. The form of tensile test piece is given in an appendix.

WIRE-ARMOURED PAPER-INSULATED CABLES FOR USE IN MINES

No. 760 : 1956. Price 5s.—This revision of B.S. 760 : 1943 follows closely on the lines of B.S. 480 : 1954, but is designed to meet the special conditions of mining practice. The specified thicknesses of insulation are greater than those required by B.S. 480 and no provision is made for aluminium sheaths or tape armour. All cables made to B.S. 760 are now required to be non-draining and the range has been extended to include 11kV screened cables. Alternative water-resisting and fire-resisting finishes are specified and a fire-resistance test is included. Like other recently revised British Standards for electric cables, B.S. 760 now contains clauses defining the composition and quality of the components.

GLOSSARY OF TERMS USED IN INDUSTRIAL HIGH-FREQUENCY INDUCTION AND DIELECTRIC HEATING

No. 2759 : 1956. Price 3s. 6d.—This glossary defines about ninety terms used in the design and use of industrial high-frequency heating equipment. It is based on a 1952 publication of the British Electrical and Allied Manufacturers Association. B.S. 2759 is divided into sections dealing with general terms (e.g., loss factor, tuning) ; types of generators, including rotating machines, valve and spark-gap generators ; equipment, such as filters, coaxial cable ; applications and methods of heating.

To conform to usage in this industry some terms have been given particular meanings differing from those in general use. For example, the term " high-frequency " is here applied to any frequency higher than mains frequency.

North of Scotland Hydro-Electric Schemes

No. VIII : THE GARRY AND MORISTON SCHEMES—PART III*

(*Continued from page 505, October 12th*)

The adjoining catchments of the Garry and Moriston rivers in Inverness-shire have for many years been recognised as favourable sources for the development of hydro-electric power. The North of Scotland Hydro-Electric Board's developments here will yield about 383 million kWh annually, from an installed capacity of 106MW. This week the description of the civil engineering works of the Garry scheme is concluded.

THE layout of the power tunnel from the Quoich reservoir, which we described last week, to the Quoich power station is fairly simple, and has some points in common with the tunnels and power station of the lower stage. The civil engineering works for the tunnels and power stations of the two stages will, therefore, for brevity, be dealt with together and preceded by some notes on Invergarry dam. The flow discharged from Quoich power station returns into the River Garry at Loch Poulary, and is then impounded again, in the relatively small reservoir and headworks of the lower stage, formed by the Invergarry dam about 10 miles further downstream.

The dam is built in the narrow gorge at the downstream end of Loch Garry. The chief problem in its design lay in accommodating all the various elements needed in the confined space of the site. Thus, although it is nominally a gravity dam, the only section which is of simple gravity construction is a short length on the right bank. The dam is shown in Fig. 7 and, following through from the right to the left bank, it accommodates a small sluice for scouring out debris on the reservoir surface; two 10ft by 15ft sluice gates, with the gate openings at the bottom of the dam, carried by a concrete buttress on each side, and with a stilling pool downstream ; a " Borland " fish lift ; intake and turbine house for two compensation water turbines ; on the left bank, in front of the entrance of the main power tunnel, an array of coarse and fine screens ; beyond the end of the screens, a spillweir discharging into the spillway tunnel, which was also used for river diversion during construction. The problem of flood water was also acute at this site, as reference to Table II *ante* clearly shows, the rise in level for the catastrophic flood being 10ft. Hydraulic design characteristics were, therefore, investigated with models. A brief description of this work has been given in the paper, " Hydraulic Scale Models," by Professor J. Allen (*Journal I.W.E.*, May, 1954, page 251), where it is pointed out that the tests gave valuable results on the discharge capacity of the side weir, and its tunnel, and also of the gates, and on the conditions of flow in the divergent channel at the exit from the tunnel and in the gorge below the dam. The reservoir raises the level of Loch Garry by 22ft and floods 600 acres of ground. Thus, the total reservoir area is about 1700 acres, the useful storage being 825 million cubic feet.

The fish pass at the dam, known as a " Borland " or hydraulic elevator fish pass, is of fairly recent origin, but is now being used on several of the Board's schemes. It was described in some detail in THE ENGINEER of April 1, 1949. Briefly, it consists of a sloping chamber within the body of the dam, with chambers at each end of it, forming pools at the upstream and downstream water levels, respectively. Flow through the chambers is controlled by various sluices to give a timed cycle of operations. Starting with water in the lower chamber at the tail water level, sufficient flow is maintained to attract fish into the chamber. After a certain interval, the lower sluice is closed and water rises up the sloping chamber, eventually reaching top water level of the reservoir, when the fish swim out. Again, after an appropriate interval, the lower sluice opens to restore the water level to its original condition at the start of a new cycle. The pass gives considerable economy over a " ladder " of pools, if the height of the dam is appreciable.

The first stage in the construction of Invergarry dam consisted in driving the river diversion tunnel. A cofferdam was then built to seal off the dam site. It consisted of two rows of steel sheet piling, filled in with rubble. On completion of the work it was decided that the cofferdam should be left in place and covered over with a 12in skin of concrete. This has enabled a small channel with stop-log grooves to be constructed, so that if the reservoir is emptied, stop-logs can be positioned so as to give a limited period during which the tunnel intake and upstream face of the dam will remain in the dry, should that ever be necessary for maintenance.

The main tunnel dips steeply from the intake and passes under the spillway tunnel. The cross-over of the two tunnels is heavily concreted. The fine screens are carried at the level of the top of the dam, on a horizontal reinforced concrete arch, which itself rests on concrete columns. The upstream abutment of the arch is prestressed vertically, to accommodate the arch thrust. The fine screens are carried on double " H "-beam assemblies spaced 6ft apart and spanning from the arch at the top to the sill of the intake. They permit two screens to be placed in any one position—in the front and back grooves—thus facilitating changing the screens. The coarse screens are supported by the sloping members of the concrete " A " frames which also support the arch. These members are structurally separated from the concrete of the sill, to accommodate any settlement. The coarse screens are fixed, but can be raked mechanically from a travelling carriage mounted on rails on the reinforced concrete arch. This carriage also has lifting gear for the fine screens.

Downstream from the dam, a small tunnel has been driven round a rock bar in the river bed, so that fish can ascend when

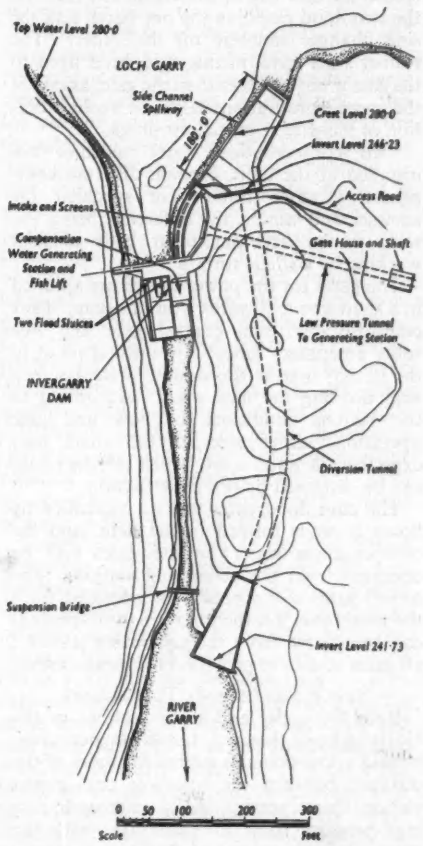


Fig. 7—Plan of dam site at the downstream end of Loch Garry

TABLE III—*Tunnels of the Garry Scheme*

	Length	Equivalent diameter	Slope	Construction
Quoich Tunnel—Total Length 14,550*ft*				
Low-pressure tunnel	12,800ft	11ft 6in	1 in 313	Horseshoe cross section, concrete lined, nominally 12in thick
High-pressure tunnel	1,440ft	11ft 6in	1 in 50	Circular cross section, concrete lined, nominally 14in thick
High-pressure pipe	820ft (140ft in trench)	11ft 6in	1 in 49·3 (1 in 26·6 in trench)	Steel pipe 1in thick, backed with concrete
High-pressure shaft	158ft 6in	11ft 6in	Vertical	Concrete lining, nominally 10in thick
Surge shaft	169ft	30ft	Vertical	Orifice type (orifice 8ft 1½in dia.
Invergarry Tunnel—Total Length 14,800*ft*				
Low-pressure tunnel	14,033ft	16ft 6in	1 in 394	Horseshoe cross section, concrete lined, nominally 12in thick
High-pressure tunnel	344ft	16ft 6in	1 in 44·5	Circular cross section, concrete lined, nominally 14in thick
High-pressure pipe	465ft	16ft 6in	1 in 44·5	Steel pipe, 1½in thick, backed with concrete
Side-stream intake to low-pressure tunnel	500ft	5ft 10½in	1 in 3	Intake from Aldernaig Burn, additional catchment 4·8 square miles
High-pressure shaft	91ft 5in	16ft 6in	Vertical	Concrete lining, nominally 10in thick
Surge shaft	112ft	60ft	Vertical	Differential shaft; riser 14ft 6in internal dia.

* No. I : " An Introductory Survey," appeared July 14, 1950 ; No. II : " The Loch Sloy Project," July 21-August 4, 1950 ; No. III : " The Fannich Project," June 8-15, 1951 ; No. IV : " The Mullardoch-Fasnakyle-Affric Project," April 11-25, 1952 ; No. V : " Some Schemes for Local Supply," October 16-23, 1953 ; No. VI : " The Tummel Garry Scheme," September 2-23, 1955 ; No. VII : " The Shira Scheme," April 20-27, 1956.

only the compensation flow is present in the river.

Flood Gates and Compensation Water Turbines

The two flood gates in the dam are of interest, because they are intended for operation in partially open positions. Operation will be so arranged that when water has to be spilled the flow will be shared equally between the two flood gates, on the one hand, and the side channel spillweir on the other. The rubber seals have, in this case, been fixed to the gate grooves rather than the gate, as one of the special precautions taken to avoid vibration of the gate at partial openings.

Two compensation water turbines are installed at the dam, because different compensation water flows were specified for summer and winter, the difference being too wide to be accommodated with efficient working by a single turbine.

The gates for the power tunnel are situated in a shaft about 50 yards from the dam. They comprise the usual control gate and free roller emergency gate. An unusual point in the design here is the doubly arched screen wall dividing the gate shaft. According to the various conditions of flow and gate operation, either side of the shaft may experience a water load, which in either case can be sustained by this construction.

The dam flood gates will be controlled by floats in wells formed in the dam, and the compensation water turbine gates will be operated from the generating station. The tunnel gates will normally be operated from the gatehouse, but their closure (not opening) can be effected from the generating station ; all gates also have provision for local control.

Surge Shafts and Tunnelling

Both the upper and lower sections of the Garry scheme have a tunnel layout comprising a low-pressure tunnel for most of the distance between the reservoir and power station, then a vertical shaft—referred to as a high-pressure shaft in Table III—with the surge shaft above it, and finally a comparatively short length of high-pressure tunnel leading to the power station, the last length of this latter tunnel being steel-lined. This arrangement has been used on several of the Board's schemes, and is now more or less the standard method, having replaced the earlier tunnel, surge shaft and penstock layout.

There is only one side-stream intake ; it is on the lower scheme, and increases the catchment by about 3 per cent. Table III gives the principal statistical data for the tunnels. Both with the Quoich tunnel and with the tunnels of the Invergarry section the extent of the work, and way in which it was done, followed normal practice, as exemplified by a number of other Scottish hydro-electric schemes. For instance, in the lower scheme the tunnel lining at the power station end was constructed from a batching and mixing plant situated outside the tunnel. The concrete was taken in in transit cars, each with a rotating drum, and was placed by pneumatic placers, using collapsible shutters 20ft long. The pressure tunnel was grouted up to 250 lb per square inch.

The arrangement of the two surge shafts, however, is worthy of note. The Invergarry section has a differential shaft, with a riser shaft in the centre, but the upper stage surge shaft is an orifice shaft. Both arrangements are shown in Fig. 8.

The turbines at the two stations are of almost equal size, but at Invergarry the head is about half, and the flow about double the corresponding quantity at Quoich (Table I). The orifice shaft gives a simple solution to the surge conditions at Quoich, but at Invergarry the size of such a shaft would have been larger, and the amplitudes of surges in it too large and insufficiently damped. The differential shaft gives economy in construction, and greater stability in operation under these conditions. In the case of a sudden drop in load, water rises up the central shaft and spills over into the outer one, thus limiting the maximum pressure (some limitation in the Quoich shaft is provided by the enlargement at the top) and reducing the period of flow through the orifices at the base. At the Ceannacroc station of the Moriston scheme, where conditions are slightly less severe than at Quoich, a simple surge shaft, without the additional throttling effect of the orifice, has been employed (the shaft is 45ft in diameter), but conditions here were influenced by the necessity for obtaining the same hydraulic conditions for the turbines as for the lower station.

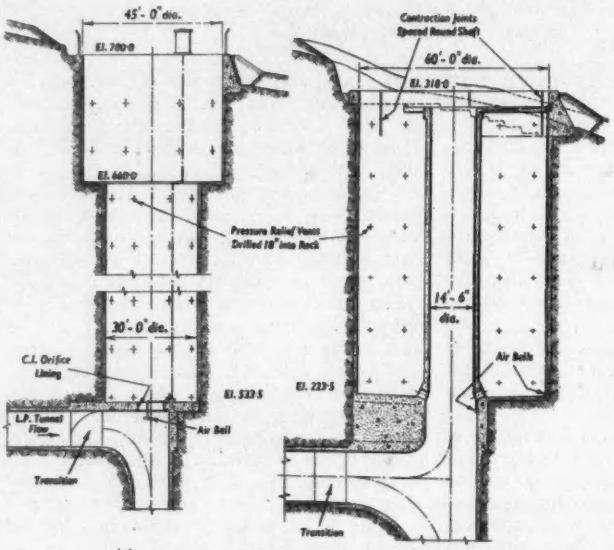


Fig. 8—Surge shaft of the Garry scheme (a) restricted orifice shaft of the upper stage, and (b) differential shaft of the lower stage

In the pipe tunnel of the upper stage concrete is packed outside the pipe and grout holes and drains are provided. Corrosion due to the acidic nature of the Highland waters is a problem which has to be faced with these pipes. Normally they are given zinc and aluminium coatings, using metal spraying techniques, and are then painted with bituminous paint. On the Garry scheme, however, the metallic coating has been omitted and bituminous paint alone was used as it is expected that this will have by itself a reasonably long life. Emphasis was laid on the preparation of the steel surface, which was shot blasted prior to the application of a primer and three coats of paint.

Corrosion problems are also met with, though generally to a less serious degree than with the steel pipes, on various iron or steel fitments which have to be fixed by embedding them in concrete, but which are otherwise exposed to river water and the weather generally. A number of such fittings on the Garry scheme have been protected from corrosion by the chromising process.

Construction of Power Stations

The principal interest in the two power stations of the Garry scheme lies in their electrical and mechanical plant, as their civil engineering design presented no undue difficulties. Both stations have had a somewhat similar architectural treatment, and both follow the Board's policy of using masonry. Burghead stone has been used on the Quoich (upper) station, but the Invergarry (lower) station has made use of stone from the tunnelling works adjoining it. Quoich station has a reinforced concrete structural frame with prestressed roof beams. The horizontal arrangement of the turbo-alternator to be discussed in Part IV simplified the civil engineering works. The turbine relief valve connects directly between the scroll casing and the tail-race channel, and needs no special culvert. The only work of this kind, apart from the main pipeline to the turbine, is a by-pass pipe for sluicing out the tunnel and pressure pipe.

The fish heck built in the river just below the station is a substantial structure, 300ft in length, consisting of a number of concrete piers, with steel screens and a catwalk between them, and with three traps for ascending salmon.

The Invergarry station is partly underground, to get the benefit of good rock foundation, only the upper parts of the walls being visible from the adjoining road. It has a reinforced concrete frame, and the lower parts of the walls consist of the rock face with a cavity and brick interior wall. The tail-race tunnel passes under the road. A constructional complication was caused here by the necessity for a relief valve. The turbine is a Kaplan machine and is, unusually, fitted with a relief valve. The channel from this valve rejoins the tail-race tunnel from above, just beyond the turbine draught tube. The two channels are steel-lined up to this junction, but a concrete surface, painted with bituminous paint, is used beyond.

The civil engineering contractors for the works described in this section of our article were as follows : Quoich tunnel and generating station, Richard Costain, Ltd. ; Invergarry works (dam, tunnel and power station), Whatlings, Ltd. The sluice gates at Invergarry dam were made by Glenfield and Kennedy, Ltd., and that firm also supplied the gates at Quoich dam and Moriston dams, mentioned in other sections. The consultants were, as previously mentioned, Sir William Halcrow and Partners.

(To be continued)

Gas Turbine Pumping Set.—The Budworth gas turbine described on page 678, May 13, 1955, has now been incorporated in a lightweight 500 gallons per minute pumping set. A Hayward Tyler water pump with an anodised high-duty aluminium alloy casing is attached directly to the reduction gear casing of the engine. A 4in suction and two 2½in delivery connections are provided, with ball seating delivery valves. The pump runs at 3500 r.p.m. on ball bearings lubricated from the turbine oil system. Priming is by an air ejector running off the compressor delivery and capable of filling the intake in twenty-five seconds against 25ft head. The set is protected by a mounting frame carrying the engine instruments and separate inlet and outlet pump pressure gauges. Weighing 150 lb, it will deliver 500 g.p.m. against a total head of 100 lb per square inch and 10ft suction burning 10/12 gallons of gas oil per hour.

Whither British Standards for Gears?

By H. E. MERRITT

The purpose of this article is to direct attention to the difficulties encountered in attempting to revise certain British Standards for toothed gears, and to prompt a wide-based discussion which may help to stimulate action in the revision of these Standards.

REFERENCE to textbooks of a century or more ago shows that the design of gears was already an extremely controversial topic, and that the respective supporters of involute and cycloidal teeth, for example, continued the mode of discussion reported of scientific societies in still earlier times. *Vide* "Rasselas": "their manners were somewhat coarse, but their conversation instructive, though sometimes too violent, and often continued until neither controvertist remembered upon what subject they began." Those now becoming long in the tooth will also recollect the lively controversy between Dr. F. W. Lanchester and F. J. Bostock about worm gear design; and the characteristic of most past arguments about gears has been a reliance upon emphasis rather than upon facts. It has been noticeable over the last few years, however, that the need to achieve ever-increasing accuracy and ever-rising performance has left those who carry the responsibility with no time or inclination for academic discussion. If, therefore, one now tries to discern the climate of opinion in regard to British gear standards, one sees two principal attitudes adopted respectively by: (*a*) those whose interests are so concentrated on the perfection of design or manufacture of gears of particular types that the refinements to which they must resort make these standards so elementary that they must be ignored; and (*b*) those who, concerned only with the design (or the purchase) of gears as parts of larger projects, and having no specialist knowledge, are content to accept the authority of a British standard. There is, of course, nothing wrong in this, provided that the standard is adequate. Whether or not this is true of British gear standards is the point now at issue.

There are now current twelve British gear standards, viz.:—

B.S. 235: "Gears for Traction" (orig. 1927, rev. 1951).

B.S. 436: "Machine-Cut Gears. A. Helical and Straight Spur" (orig. 1932, rev. 1940).

B.S. 545: "Bevel Gears (Machine Cut)" (orig. 1934, rev. 1949).

B.S. 721: "Machine-Cut Gears. C. Worm Gearing" (orig. 1937, amended 1941).

B.S. 978: "Gears for Instruments and Clockwork Mechanisms" (orig. 1941, rev. 1952). Part 1, "Involute Spur, Helical and Crossed Helical Gears." Part 2, "Cycloidal Type Gears." Part 3, "Bevel Gears."

B.S. 1498: "Gear Hobbing Machines for Turbine and Similar Drives" (orig. 1954).

B.S. 1807: "Gears for Turbines and Similar Drives." Part 1, "Accuracy" (orig. 1952).

B.S. 2007: "Circular Gear Shaving Cutters: Accuracy" (orig. 1953).

B.S. 2062: "Gear Hobs" (orig. 1954).

B.S. 2518: "Rotary Form-Relieved Gear Cutters" (orig. 1954).

B.S. 2519: "Glossary of Terms and Notation" (orig. 1954).

B.S. 2697: "Rack Type Gear Cutters" (orig. 1956).

This list shows that seven of the above standards have been issued, as new standards, since 1952. Of the remainder, B.S. 235 ("Gears for Traction") and B.S. 978 ("Gears for Instruments") have been issued in revised form in 1951 and 1952 respectively; and these are mainly dimensional. This leaves the three specifications: B.S. 436, "Helical and Spur Gears," last revised 1940; B.S. 721, "Worm Gearing," last amended 1941; and B.S. 545, "Bevel Gears," revised 1949. From this it is evident that we have two groups of specifications. The first group (covering eight of the nine most recent issues) primarily concerns dimensions for interchangeability and accuracy; and these have been produced fairly quickly. The second embraces the three major specifications for helical and spur, bevel, and worm gears, and these deal not with dimensions affecting interchangeability, but seek to lay down a complete code of practice covering detail design, accuracy and permissible loading. If all the standards are to be passed under critical review, different criteria must be applied to these two groups.

Dimensional Standards

The value of the majority of British Standard Specifications resides in their standardising of dimensions and/or manufacturing techniques for securing interchangeability and controlling accuracy, and the advantages accruing from this in economy and facility of manufacture or supply are so generally recognised that they need not be further elaborated here. This principle cannot be rejected out of hand in the case of gear cutters and gear cutting machines. How far the principle can usefully be taken in practice where gears are concerned is another question. In so far as the dimensions standardised affect the mounting of gear cutters, there should be no problem, but merely the reservation that developments in technique may lead to changes in the general dimensions of cutters which require new standards.

The intricacies of gear tooth geometry, however, call for refinements in cutter tooth form which reflect the design and production problems of the finished gear, the type of cutter, the type of cutting or generating machine and the special (and changing) techniques of the makers of cutters and machines. There are no British Standards which specify all the essential details of tooth design of any type of gear generating cutter (except B.S. 2697, which is of limited interest); these details are left to the maker of the cutter. Any user of a gear shaving machine, for example, who expected good results from shaving cutters ordered merely to B.S. 2007, and cut the gears by hobs ordered merely to B.S. 2062, would invite trouble. This does not often happen, because purchasers of gear cutting tools expect the supplier to take the responsibility for producing a satisfactory job, and if the job proved unsatisfactory they would certainly not be fobbed off by the contention that the cutters were in accordance with a British Standard.

The history of the development of gear manufacture offers no grounds for believing that effective standards for the form of the teeth of cutters for the production of high-quality gears will be necessary, or possible. By "effective" is meant that all cutters conforming to the same standard would produce equal results. It is hard to believe that anyone would wish to establish standards for low-quality gears. The useful limit in cutter standardisation would therefore appear to be to ensure interchangeability on gear cutting machines.

What could be of value, however, would be the establishment of standards to aid the preparation of well-dimensioned and properly toleranced drawings of finished gears. In the case of simple spur or helical gears, the draughtsman often does not know whether they will ultimately be cut by hobbing or gear shaping, particularly if the cutting is sub-contracted. The sub-contractor will probably have a varied stock of hobs and cutters, but there are still several different systems in use for the tooth proportions adopted for the cutters, even apart from profile, thickness and root clearance modifications to suit the requirements of, for example, profile grinding or shaving. The tooth proportions given in B.S.S. 436 are over-simplified and inadequate. More thoroughly considered standards for tooth dimensions framed in the light of the peculiarities of the different cutting processes might, by commanding more respect, stand a better chance of more general acceptance.

Something ought also to be done about tolerances. It is common to see, on gear drawings, specified limits of error of profile, or of adjacent and cumulative pitch error, possibly according to B.S. 436, when the physical equipment for checking pitch errors (particularly cumulative pitch error) is non-existent, and when nobody can tell, until the gears have been finished and mounted and run, what kinds of error are significant, and what can be safely accepted. On the other hand, the limits to be held on a rolling gear test, which is a common and very useful inspection check, and the distinction to be observed between tooth thickness tolerance and backlash tolerance, are not indicated as often as they should be. To put it very briefly, dimensional gear standards should be more closely related to machine shop practice.

Glossary

B.S. 2519, "Glossary of Terms and Notation," is intended to relate to all the other gear standards, in order to avoid duplication. Hence, no other standard is complete without it. Ignoring the chance of their becoming separated, one might consider the people by whom the standards are expected to be used. These people are not technical directors or chief engineers, but the chaps on the shop floor and in the drawing-office and planning and inspection departments. Few of them have suffered university instruction in analytical plane and solid geometry, but give them a clear and simple picture and they will apply it quickly to the job. Make it complicated or abstruse, or give new names needlessly to old things, and they will react in a very proper manner. The definitions in the Glossary are, for the most part, intelligible and meaningful only to those who are really well versed in gear geometry. Such people are in a small minority and do not need a British Standard to refresh their memory—and in any case they probably conceive the definitions in simpler terms. A few examples illustrate the general character of these B.S. definitions:

1402 *Cylinder of Generation.*—The pitch cylinder of the gear when meshed with its

generating cutter, the latter being regarded as the mating gear.

1404 *Pitch Cylinders.*—The contacting cylinders, co-axial with the rotation of the gears, on which the normal pressure angles are equal.

1407 *Reference Cylinder.*—The cylinder on which the normal pressure angle has the specified standard value.

These three examples are cited together, not merely to indicate how needlessly complicated each is, but to show the difference between trying to transform words into pictures, and putting pictures into words. The visual concept actually underlying the above definitions is within the capacity of a young apprentice, but he would not see the picture behind the words without having it explained to him with the aid of complicated diagrams involving the action of involute profiles at varying centre distance. He might well fail to understand the explanation. But he would understand that pitch is the spacing of the teeth, and that a pitch circle is a circle round which the teeth are spaced. A sketch of a circle with equally spaced dots round it would make it clear. He would easily associate this "pitch circle" with teeth spaced according to the specified pitch. The "reference cylinder" defined (*sic*) above is just this, giving a new name to an old concept, with "cylinder" replacing "circle" just to turn a simple two-dimensional concept into an unnecessary three-dimensional one, and confused by the quite needless introduction of the normal pressure angle. Definition 1404, "pitch cylinders," makes confusion worse confounded by giving an old name to a new concept; these are rolling cylinders on which the tooth spacing is different from the specified pitch.

Another example is provided by definition 1332, "tooth trace." This is "the line of intersection of the tooth flank with the surface of the reference cylinder or pitch cone." In happier days this was called the "pitch line." This is an accurate and graphic term, whereas "trace" is non-descriptive and unfamiliar. The line of thought that led to the change can, of course, be discerned. Some people, the writer included, speak of "pitch line velocity" when "pitch circle velocity" would be more precise (but more trouble), and the pitch circle of a rack becomes a straight line and thence the "pitch line." But why worry if the same term has different meanings in different contexts, so long as the meaning in any given context is understood? Must we find a new name for a matchbox? Friction-ignitable-splint-container?

The scope of the Glossary has been expanded by including in it all the terms used in the "design" specifications. The introduction of these terms into the original specifications, and their transference to the Glossary, suggests that they are fundamental and important and gives them a spurious appearance of value and of permanence. Several are baseless and ephemeral. If, however, the specifications were revised and restricted to cover only the things that they can usefully cover, so that they no longer lie uneasily between standards and textbooks (satisfying the purposes of neither), then the Glossary would become unnecessary.

Codes of Gear Design Practice

The subject matter of the three principal gear specifications covers tooth design, tolerances and permissible loading.

The dimensional interchangeability of individual gears (as distinct from gear pairs or sets) furnished by different suppliers is not often desired. All gears are potentially full of trouble; firms whose practice it is to order gears or cutting from outside suppliers rarely have inspection equipment which will serve to check gears with sufficient thoroughness, and divided responsibility for gear performance is best avoided by having the same supplier finish mating gears. The difference between gears of the same general type may reside, in some cases, in the initial selection of tooth proportions by the designer. Gross design errors, manifested by badly undercut teeth, are occasionally encountered; but there are many systems of tooth design which enable all serious pitfalls to be avoided and one such system is presented in each of the three principal gear standards. Each is neither the best nor the worst in its field.

The difference between good and bad gears of the same nominal design is chiefly a matter of errors in tooth form. The most frequent ultimate test is quietness of operation, together with superficial evidence of the quality of workmanship as indicated by surface finish and tooth bearing. Noisy operation is the result of combinations of errors of many kinds, and only after considerable experience of a particular gear application is it possible to forecast quietness from measurements. No "standards of quality" expressed in terms of tolerances on the many kinds of error can give a reliable indication of the behaviour of the gears, which depends not merely on the particular combination of errors present, but usually demands departures from strict kinematic tooth profiles and tooth spirals of roughly the same order as the probable errors. These departures or modifications must be found by trial.

The estimation of permissible loading remains empirical. In the resulting formulæ, an apparently rational relationship showing the effect of known variables, such as numbers of teeth, pitch diameters, speed and the like, is apt to distract attention from the fact that innocent-looking constants, such as a permissible working stress, or the traditionally accepted "speed factor," are guesses containing more or less inspiration, according to the judgment and field of experience of the guesser. It cannot be otherwise when so little qualitative information exists about such things as the effect of cyclic loads of variable peak value on bending fatigue, and the relationship between the theoretical and the effective stress concentration for high-duty gear materials; when the physics of lubricated line-contact motion are scarcely understood, and then the overall dynamics of the geared system are ignored because the analysis is too difficult or impossible.

The rules for design contained in the specifications in question cannot, therefore, rightly be classed as "standards," even (for the reasons already given) those on gear tooth tolerances. The term "recommended practice" would be an overstatement, since it carries the implication that such practice is superior to any other. "Approved practice" would be better, as indicating an acceptable degree of competence. But, however described, the rules represent a code of practice rather than a standard. A code of practice is in essence empirical or arbitrary. It is devised and agreed in situations where no one best solution can be demonstrated, and where those who subscribe to the code attach more importance to the advantages of conformity than to the abstract correctness of the practice *per se*.

The many years which have elapsed since the last revision of the three main gear standards might prompt the belief that they have remained unchanged because they have remained acceptable. The truth is otherwise: they have not been revised because the only point of agreement reached is that revision is necessary. But the contents of these specifications are still described as "Standards" and still carry the authority of the British Standards Institution and the formidable list of "co-operating organisations."

What is the actual effect or influence of these standards on current engineering practice? There is no simple answer to this; it is necessary to consider typical cases. These are best selected with reference to the responsibilities of the different kinds of engineer who are concerned with gears. The most important groups are as follows:—

(*a*) Those who design gears as vital power-transmitting components of more complex machines, whose aim is maximum performance at minimum size or weight, and who design gears for production in their own factory. Outstanding examples in this group are found in aircraft and automobile engineering, and in marine reduction gearing. Design practice will include detailed and advanced studies of gear technology, constant analysis of past and present practice, experimental work in search of improved performance, and awareness of the effects of all aspects of manufacturing techniques and problems on design practice. This is the field from which progress in gear engineering comes, and it is safe to say that B.S. 436 figures not at all in it.

(*b*) Those responsible for technical development in companies specialising in the manufacture of gear cutting tools or machines, or in restricted classes of gear of which they have special knowledge. This class is parallel to (*a*) above, in requiring advanced studies which leave British gear standards far behind.

(*c*) Those who design gears as minor components of more complex machines, in which gear types and dimensions are decided by expediency, and the cost or performance of the gears are not important enough to justify a high degree of specialist knowledge and effort in their development. If, as is common in this general case, new gear design problems arise but seldom, a British gear standard may be consulted. It will serve as a source of technical information but rarely as the basis of a contract for the supply of the gears, if the latter are bought finished from, or cut by, outside suppliers. (It is the writer's experience that when gears are bought out to a British gear specification, the specification is often misinterpreted or is inadequate, with much resulting confusion, particularly B.S. 721.)

(*d*) Those concerned with that part of the specialist gear industry which manufactures proprietary gear units for industrial application (possibly as part of wider interests). A characteristic of this branch of the gear business is the inflow of relatively large numbers of inquiries and orders for which standard gear units are offered. Standardised horsepower rating formulæ applicable to a wide range of conditions then become a practical necessity. The rating formulæ in B.S. 436 were, in fact, based on experience with helical reduction gear units and embody margins of safety appropriate to the design and manufacturing techniques used for such gear units.

B.S. 436 can, therefore, be regarded as a code of practice for the design and rating of gears accepted by manufacturers of proprietary gear units. This is something which those manufacturers are clearly entitled to do. Revisions of the code of practice are matters for the manufacturers only to agree,

since they accept responsibility for the result.

Gear Tooth Design Systems

Some additional comment may be desirable under this heading. The technique of gear tooth design has been evolving ceaselessly for more than a century, and the literature abounds with discussions of the elimination of undercutting, minimum numbers of teeth, correction (now "addendum modification") and other aspects of involute gear tooth geometry. These discussions were prolonged because of the persistence of the 14½ deg. pressure angle, which aggravates most tooth design problems unless skilfully applied. When B.S. 436 appeared, the 14½ deg. pressure angle was still common in ordinary industrial practice, although 20 deg. had become usual in automobile transmissions, but often with stub-tooth proportions. The tooth design methods set out in B.S. 436 were based on 20 deg., together with increased bottom clearance and cutter tip radius and adequate rules for addendum modification. These in combination represented a substantial improvement on average practice at that time (1932). But other systems were also known, such as the Maag system based on 15 deg. with well-chosen addendum modification.

Tooth design of spur and helical gears in the last two decades, however, has advanced much further, notably in the field of high duty gears. The trend has been towards still higher pressure angles, and highly-developed profile modification differing radically in conception and magnitude from the arbitrary "tip-easing" of the British Standard "basic rack." There has thus been an ever-widening divergence in the degree of competence applied to gear tooth design, since skill at the highest level has vastly improved whilst at the lowest level it has not. It would be possible at the present time to formulate a large number of systems for gear tooth design, all showing advantages of one kind or another over that of B.S. 436. These advantages, however, can be assessed only approximately, owing to lack of fundamental knowledge. It is unlikely, therefore, that any one system applied universally would give the best results in every case.

It is in consequence questionable whether either the continuance of the old system of B.S. 436, or any one new system to supersede it, would be desirable. If the function of British Standard Specifications were conceived to be educational, any reasonably good system might serve to prevent some unskilful designer from perpetrating a blunder (and this still happens). But it could also have the effect, by virtue of the authority which it carries, of freezing thought and practice. It is sometimes suggested that standardisation in general tends to stultify progress, and nearly always this is a short-sighted argument which can quickly be demolished. But in the case of gear design technique it is, in the writer's opinion, true.

The practical advantages to be derived from the inclusion of gear tooth design data in a British Standard are limited to improving the supply potential of the cutters for general commercial gear-cutting work. For this purpose it is sufficient to standardise a range of pitches, and the pressure angle and dedendum of unmodified gears which the cutters can produce. Such cutters would be restricted in their application to gears not subject to a subsequent finishing operation such as shaving or profile grinding. From these standard cutters, an infinite variety of modified gear tooth designs can be obtained, at the designer's discretion.

In the case of bevel gears, the design of the cutters is so closely associated with the design of the generating machines, which are being produced in increasing variety by different makers, that national standards appear impracticable. Makers' own standards, however, cover the requirements of the supply problem.

The likelihood that any standardisation of worm gear design will increase the availability, from different sources, of tools which will produce interchangeable gears, appears extremely remote. A partial step would be the standardising of a range of centre distances and ratios, from which designers of new worm drives might be able to make a selection for which tools are likely to be available. The system of coding worm gear designs contained in B.S. 721 also makes it easy to ascertain, from a maker's list of hobs correspondingly classified, what existing tools might be worked into a new design. But, beyond that, the details of tooth and tool design are of no significance from the point of view of standardisation, because the question of interchangeability of either gears or tools from different suppliers arises in practice so rarely that it can be ignored.

Tool availability is of importance only in the case of general commercial batch work. When quantities are large and regular, tools require to be renewed continually. The opportunity can then be taken of producing the best possible design of gear, without the restriction of standards.

The Questions Arising

Having said, in substance, that current British gear standards either go too far or do not go far enough, some constructive suggestions ought to be advanced. But in order to do this many questions first need to be answered. Some of these are as follows :

(1) For whose particular benefit is any particular standard intended ? Is it the user of the gears, the manufacturer of the gears, or the manufacturer of the tools (machine tools or cutters) ?

(2) What defined benefit is sought in each case ?

(3) If the beneficiary is the user, what must be specified in order to establish standards covering (*a*) quality, (*b*) interchangeability, (*c*) ease and latitude in supply ?

(4) If the beneficiary is the manufacturer of the gears, what are the proper subjects or items for standardisation ? Conversely, what kinds of standard might prejudice his power of initiative or restrict the application of special knowledge and skill which he may develop in particular fields ? What kinds of standard under this heading should be national standards (in which user interests are represented) and what are more fittingly subjects for agreement between manufacturers only ?

(5) If the beneficiary is the manufacturer of the tools, most of the questions under (4) also apply.

(6) What is the experience or opinion of users and manufacturers in regard to standards already issued ? Which parts are useful and which are not ? If not, why not ?

(7) What new items ripe for standardisation can be agreed to be necessary by the various interested parties ?

(8) What are proper subjects for international gear standards, and why ?

(9) Amongst British Standards other than those for gears, codes of design practice exist in some fields but not in others. Can any clear principle or policy be extracted from these cases, and, if so, is it applicable to gear design ?

Any answers ?

National Federation of Engineers' Tool Manufacturers

World trade and the Australian market formed the subjects of the speeches which followed the annual dinner of the National Federation of Engineers' Tool Manufacturers in London last week. The president of the Federation, Mr. R. A. Balfour, pointed out that the branch of industry it represented was responsible for producing some £30,000,000 of tools annually, and of this 10 to 25 per cent was exported. The industry had to meet a continual challenge presented by new production methods and machines. The fact that many countries overseas who had been good customers were now undertaking the manufacture of certain classes of goods hitherto imported was laudable and did not mean that they would not continue to be importers of new and special tools. In this respect, said Mr. Balfour, markets such as that of Australia presented a challenge to the British tool industry. The next speaker, Sir Edwin McCarthy, the Acting High Commissioner for Australia, dealt at some length with world trade and the position of Australia. He pointed out that the present currency restrictions, which had been imposed by Australia, were caused by force of circumstances resulting from a lack of foreign currency. This had been largely brought about by the small range of goods Australia had available for export and the competition they had to meet owing to the subsidising of exports and similar practices of other countries. What was needed was a change in the established range of exported goods, and the methods of trade between the under- and the well-developed industrial countries of the world. Sir Edwin said that British industrialists would do well to study more closely the changing pattern in the imports required by such countries as Australia, where increasing home production gave a growing self-sufficiency in consumer goods. There was a trend for the demand for consumer goods to decrease and this demand would be replaced by one for capital equipment which industrialists should anticipate.

James Watt Dinner

On October 4th there was held in Glasgow the annual James Watt Dinner of the Institution of Engineers and Shipbuilders in Scotland, an Institution which will celebrate its centenary in June next year. Sir Harold Yarrow, who was in the chair on the occasion of the dinner, will be the Centenary Year President. After the toast of "James Watt" had been honoured in silence, Sir Victor Shepheard proposed the toast of "Engineering and Shipbuilding." His main theme related to the increasing difficulty in recruiting sufficient graduates for those industries. Demand exceeded supply, and not sufficient youngsters of first-class ability seemed to be attracted to engineering and shipbuilding as a career. Other countries were experiencing the same problem, and he referred to action being taken in Russia, the U.S.A., Germany, and Japan to increase the supply. Our own Government was taking similar action. But governmental action towards the expansion of universities and technical colleges was not in itself enough. Boys needed to be convinced that a career in engineering or shipbuilding was at least as attractive as in any other profession. He felt that the engineering institutions should set up a national committee to study what it was that made particular careers attractive and what more could be done to make a career in engineering attractive. In replying to the toast, Professor Robb pointed out that the Institution owed its inception to McQuorn Rankine in 1867. "The Guests" was proposed by Mr. J. C. Robertson, Hon. Treasurer of the Institution, and Mr. P. L. Jones, President, North East Coast Institution of Engineers and Shipbuilders, replied.

LETTERS AND LITERATURE

Letter to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

NEVER BE SHORT OF LABOUR

SIR,—In a recent issue of your journal a leading article made reference to the advice "Never be short of labour if you want to prosper." This was parodied by "Never be short of machines if you want to prosper." Quite so; conditions to-day support such advice—but what of conditions to-morrow?

Pondering over the prospect, I am led to wonder what the future has in store for man. Will we become so mechanised, so dependent on mechanisation, that man will idle? By "man" I refer, of course, to the majority who will not be able to find employment in making or maintaining the mechanical wonders of their day. The day of full "automation" may still be so far off that we or our children may not see it—but the trend of development points unmistakably to that goal.

There is in industry already an awareness of the problem. Say the word "redundancy" and immediately it is drowned by cries of "strike!" Then union leaders press for reinstatement of the cast-off workers, while employers search for an economic solution to the great problem which faces them. They know, the unions know, and the workers know, that the march of progress demands changes in outlook, in management and in relationship of effort and reward.

The object of the great exercise "Automation" is to improve the lot of man. (If this is untrue then the quicker we stop it the better.) The great theory guiding the development is based on efficiency in production. By increasing the number of units produced per man employed then the unit cost is reduced. These are all well-known arguments and make sense. They make sense if man continues to have a sufficient income! But they are complete nonsense if efficiency is achieved but man is deprived of his income! Of what value are "cheap" goods if man has not the money to pay for them?

These thoughts on the consequences of progress lead me to the conclusion that man may be compelled to idle unless he can turn his energies to the Arts (I regard sports as a form of idleness, though many would disagree with me, and, anyway, they are too internationally provocative to take so seriously). He must, however, receive sufficient rewards for what little effort he expends to be able to luxuriate in the midst of the plenty which efficiency heaps upon him. If benefactors fail him and he cannot buy, then shall the cry "redundancy" be raised again, but this time it will be against the machine!

I find this picture of the future, for which we are all striving, too depressing to contemplate and I write in the hope that someone will tear it to shreds and present a much more hopeful one. It is, after all, too shattering to think that any "Teddy Boy" of to-day, who idles away his time and lives on State benefits, may not be so deplorable as we think; he may be ahead of his time, that's all; a living example of the worker of the progressive future.

W. F. WRIGHT

Hereford,
September 26th.

Literature

An Introduction to Electrostatic Precipitation in Theory and Practice. By H. E. ROSE, D.Sc. (Eng.), Ph.D., M.I.Mech.E., A.M.I.C.E.; and A. J. WOOD, M.A.Sc., B.Sc. (Eng.), A.M.I.Mech.E., A.M.I.E.E. Constable and Co., Ltd., 10, Orange Street, London, W.C.2. Price 17s. 6d.

IN his Foreword, Professor A. H. M. Andreasen remarks that "obviously the subject is not yet well enough understood to allow the writing of textbooks while design data are the carefully preserved secrets of the manufacturers," but nevertheless by collecting together from widely scattered sources the available information the authors have achieved a useful presentation of existing techniques. The introductory chapter discusses the ability of electrostatic plant to deal with vast volumes of gas and to extract efficiently microscopic organisms, pointing out that its cost may well be justified by recovering tar or other materials from the gas stream; the limitations, compared to, say, washing plant, are also stressed. After developing the electrical theory, the authors turn to precipitation efficiency; they are sceptical of exponential extraction/distance relationships, and describe work of their own, which suggests that completely dust-free zones are created, particles in the effluent having been re-entrained. This leads to a discussion of what materials can be extracted, solids of low resistivity being re-entrained heavily and solids of high resistivity leading to back ionisation. The latter materials, with resistivities above 10^{10} ohm-cm, can be precipitated in the presence of moisture or some conducting agent. The design and construction of a precipitator and the rapping gear needed to free the electrodes of dust are outlined, together with the electrical supply. There is no bibliography, references being given at the end of each chapter; names, including Anon., and subjects are separately indexed, not without errors.

The Design of Wing Sections. By T. NONWEILER, B.Sc., A.F.I.A.S. Bunhill Publications, Ltd., 12, Bloomsbury Square, London, W.C.1. Price 3s. 6d.

THIS is an *Aircraft Engineering* monograph, reprinted from the issue of July, 1956. It is not only comprehensive, but also exceedingly readable. The author discusses the gradual advance of empirical sections, almost without benefit of theory, and the immense amount of wind tunnel investigation involved.

A very full description of the qualitative theory of laminar flow wings is then given, and even here we see practical considerations dictating departures from theoretical ideals—for instance, in the desire to increase nose radii to improve low-speed characteristics. The even more acute problems of maintaining the theoretically stable laminar flow are touched upon, and the objectionable characteristics of wing air intakes discussed. The powerful influence of suction to obtain an approach to inviscid flow is shown to lead to unconventional but attractive sections of great thickness. Blowing, particularly as exemplified by the jet flap, is treated in a single phlegmatic paragraph; it is not easy to accept the implications of: "these shapes have no application outside their specifically designed purpose."

The account of high-speed subsonic sections develops naturally from the description of low drag forms. The fact that supersonic flow is more simply predicted in theory and realised in practice is reflected in a very brief account of aerofoils for this *regime*: viscous drag and separation problems are not discussed. The Area Rule as applicable at M.1·0 is outlined. The extreme variety of sections designed for different Mach numbers, plan forms, and performance criteria is illustrated.

This survey of a field upon which so much design effort has been lavished is likely to appeal to the aerodynamicist anxious to take a step away from his canvas, and almost certain to enthral workers in other fields with its lucid derivations of subtle design compromises.

Performance Criteria of Gas-Turbine Combustion Chambers. By D. B. SPALDING. Bunhill Publications, Ltd., 12, Bloomsbury Square, London, W.C.1. Price 4s.

THIS monograph, reprinted from the April and May, 1956, issues, is intended to establish a basis of comparison for combustion chambers. The aerodynamic flow characteristics and combustion intensity are reduced to dimensionless criteria to give the most general applicability. A simplified concept of a two-stream chamber is postulated to expound the influences of overall fuel/air ratio.

Theory of Machines. Third edition. By T. BEVAN, B.Sc. Tech., A.M.I.Mech.E. Longmans, Green and Co., 6 and 7, Clifford Street, London, W.1. Price 26s.

EDITIONS of this volume have appeared at intervals of thirteen years. The latest contains additional matter in the section on gyroscopes which, however, is still confusing on the subject of stabilisation; the use of motor-driven fins on ships is not mentioned. Also enlarged is the treatment of epicyclic gears; in addition to direct computation, four methods—algebraic, tabular, graphical, and vector—are given for determining gear ratios in such trains. With such an armoury the student should readily discover that the answer given to an example on the Ford "T" transmission is palpably wrong. There are both index and bibliography.

Books Received

The Chemistry of Cement and Concretes. Second edition. By F. M. Lea. Edward Arnold (Publishers), Ltd., 41, Maddox Street, London, W.1. Price 70s.

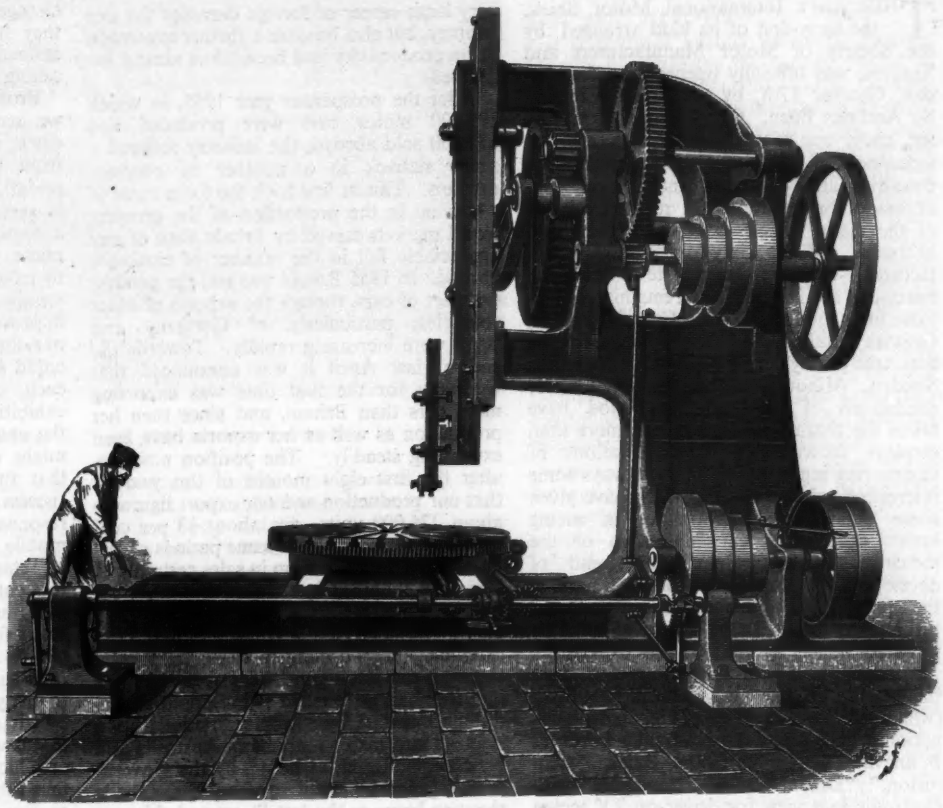
Disposal of Sewage and other Water-borne Wastes. By Imhoff Müller and D. K. B. Thistlethwayte. Butterworth's Scientific Publications, 88, Kingsway, London, W.C.2. Price 45s.

Machinists Ready Reference. Compiled by C. Weingarther. Prakken Publications, 330, Thompson Street, Ann Arbo, Michigan, U.S.A. Price 1.50 dollars.

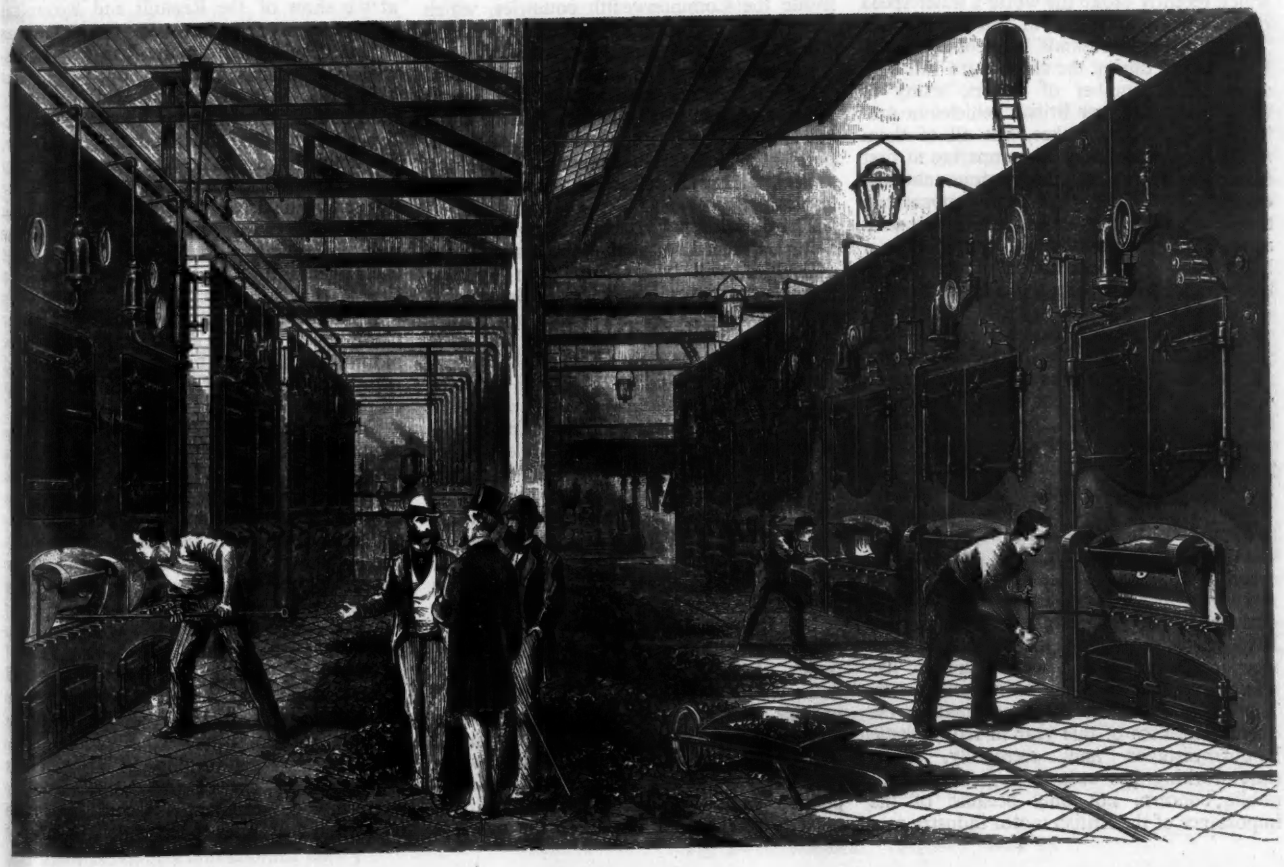
Introduction to Stud Welding. By W. T. Amison. The Association of Engineering and Shipbuilding Draughtsmen, Onslow Hall, Little Green, Richmond, Surrey. Price 3s.

ENGRAVINGS OF 1877

The slotting machine for "heavy work," which is illustrated by this engraving, was made by W. Collier and Co., of Salford, and described in our issue of April 13, 1877. We commented then on "the great care taken in its design and construction to insure uniformity of strength in all the details, so that the heaviest cuts may be taken without either danger of breakage or springing in the machine." The description says: "The machine takes in articles 13ft 6in diameter, and has an adjustable stroke up to 4ft. The circular table is 8ft diameter, and has worm teeth cut from the solid metal in its periphery, for self-acting circular motion. The traverse of the tables is 8ft longitudinally and 8ft transversely, and self-acting variable feed motions are employed in the longitudinal, transverse and circular movements, while a quick hand motion is also fitted to each"



The engraving below, which is reproduced from our issue of May 4, 1877, shows the interior of the boiler-room at Havemeyer and Elder's "sugar house" at Brooklyn, U.S.A. In all, there were fifteen boilers, the furnaces being fitted with fire doors and grates manufactured by Martin and Co., Charterhouse Street, London. This door, our description states, "answers the purpose of a deflector, and sends in air over the burning fuel in a very wide and thin stream. The grate bars are square and turned with a key in order to clean the fires"



International Motor Show

No. I

THIS year's International Motor Show, the forty-first of its kind arranged by the Society of Motor Manufacturers and Traders, was officially opened last Wednesday, October 17th, by the Prime Minister, Sir Anthony Eden. Once again visitors may see, under one roof, the latest cars from the industries of most automobile producing countries and compare, under ideal conditions of presentation, the respective merit of the many vehicles sent from home and overseas. Of the sixty-four motor manufacturers showing their latest products, thirty-one are British ; the remaining thirty-three firms are from U.S.A., Canada, France, Germany, Italy, Czechoslovakia and, for the first time at any London Motor Show, from Sweden. Although most international motor exhibitions of the post-war period have taken the character of trade fairs more than displays showing the latest creations of engineering ingenuity, there are always some interesting exhibits of cars which have given some outstanding performance in racing events during the current season or are indicative of some particular trend of development. Exhibits of this character at the present show include the Rover gas turbine car in its latest form ; a similarly powered vehicle by the Renault Company ; the Lotus new Formula II racing car ; the Austin Healey modified " 100 Six " (which lately created twenty-eight new international and American national records at Bonneville Salt Flats); the Buick " Centurion," "Dream Car of To-morrow" with electronic rear view for driver on TV screen obtained through a closed-circuit TV camera enclosed in the boot ; and Mr. Donald Campbell's turbo-jet hydroplane " Bluebird," which recently broke the world's water speed record for the third time in fourteen months.

Among the thousands of people visiting Earls Court during the show there will be a considerable number of buyers, many of them anxious to buy British vehicles in preference to foreign makes, but all of them sufficiently experienced in comparing at first hand the merits of the various nations' automobile designs, their price, appearance and—last not least—their individual sales appeal. On their verdict and, probably to a lesser extent, on the reaction of the foreign trade press, will depend whether or not the British motor car industry will be able to overcome the severe setback received this year as a result of sales difficulties at home and abroad. It is obvious that the occurrence each year of such events as the Paris Salon de l'Automobile and the London Motor Show should stimulate newspapers and other periodicals to devote some of their space to the discussion of questions, technical or economic, which have some bearing on the present and future development of motor transport. This year all British papers and a considerable part of the foreign press have given prominence to reports on the economic position of the British motor industry and have tried to analyse the causes for the recession which, in the recent months, has affected some of the motor manufacturers. The crisis which became so evident in the opening months of this year in redundancy, labour disputes and, eventually, short-time working has caused a great deal of public concern, not only because of the importance of the British motor industry as a very large earner of foreign currency for this country, but also because a further expansion of its productivity had been taken almost for granted.

After the prosperous year 1955, in which 897,000 motor cars were produced and 373,000 sold abroad, the industry suffered a sharp setback in a number of overseas markets. This at first took the form more of a decline in the proportion of the growing world markets served by Britain than of any appreciable fall in the number of cars sold abroad. In 1955 Britain was still the greatest exporter of cars, though the exports of other countries, particularly of Germany and Italy, were increasing rapidly. Towards the end of last April it was announced that Germany for the first time was exporting more cars than Britain, and since then her production as well as her exports have been expanding steadily. The position now, i.e. after the first eight months of this year, is that our production and our export figures—about 226,000 units—are about 13 per cent down compared with the same periods of last year. Severe as this drop in sales certainly is, it is partially offset by the fact that many car manufacturers also make commercial vehicles, in which field the demand has increased considerably. The decline in sales, to a great extent, is due to circumstances over which the industry has no control ; indeed, the conditions imposed by severe restrictions upon imports into major markets in Australia and New Zealand and, at home, by the Government's general " credit squeeze," have made the year between the last Show and this one the toughest on record in the post-war era for our manufacturers. It is not possible to foresee whether the present sales difficulties inside the Commonwealth countries, which are caused entirely by economic circumstances, will be overcome in the near future ; for the time being the industry has to accept the facts as they are and, further, has to become reconciled to the idea that in home markets we may be approaching a saturation point at which the inadequacy of our road system will make private motoring less and less attractive.

The question is whether our motor manufacturers, faced with the above-mentioned difficulties, will be able to open up new markets or recover those which in the last few years have been lost to Continental competitors. The motor industry, of course, is fully aware of the seriousness of the present situation and considers this year's show to be the most important since the end of the war ; more than ever the sales appeal of the British cars on view will decide whether or not the regression of export sales in free markets can be slowed down and eventually reversed. The industry appears to be quite optimistic in this respect. According to a statement issued by the Society of Motor Manufacturers and Traders at a recent press conference, it is maintained that British cars are designed to meet the impact of world conditions. The present and the future policy of the British industry is " not to make change for the sake of change, but to provide cars which have passed their tests and qualified. The industry believes in the answer given at this year's Motor Show which will put the fullest limelight on the competitive value of the latest models." We must leave the final verdict to the overseas buyers and the representatives of the foreign technical press. It is doubtful whether they will so easily agree that foreign manufacturers are likely to indulge in the expensive experiment of making " change for the sake of change " ; on the contrary, any drastic changes in the overall conception of cars they have made, have generally proved of eminent practical value and have created new selling points at the expense of our industry.

From the point of an unbiased observer, we are inclined to suggest that this year's show does not display any marked change from previous styles, nor are there any remarkable or novel technical innovations. It seems that the British industry assumes automobile engineering to have passed the phase of new post-war developments and to have settled down to a state governed by steady, though less spectacular, detailed improvement. It is true that there is hardly one automobile factory in the world which could show a new model at the occasion of each of the great annual international exhibitions. Indeed, nowadays, apart from the enormous costs involved, such a policy might easily be regarded as an admission that the previous models were not a full success ! On the other hand, the men responsible for the future of the British automobile industry must be aware of the peril of stagnation which is attendant upon too conservative a policy, and we believe that they should not be satisfied to cater solely for contemporary demands, but should aim to anticipate future requirements.

It has been our practice in recent years to analyse our impression of the Motor Show by giving a short survey of the prominent trends which either govern the present design or which give an indication of the direction that future development might take. As far as future development goes, there is little doubt that the gas turbine will eventually replace the piston engine and from this point of view we welcome the appearance at the show of the Renault and Rover gas turbine cars. The latter is powered by an engine developed from the " IS/60 " industrial gas turbine marketed by Rover Gas Turbines. It is of the two-shaft type with independent h.p. and l.p. turbines, respectively driving the centrifugal air compressor, and delivering useful power. The compressor has a maximum speed of 52,000 r.p.m. and the power turbine drives the output shaft through a two-stage reduction gear. The turbine unit is fitted with a plate type heat exchanger and is said to be only half the size of that fitted to " JET 1," the world's first gas turbine car introduced by the Rover Company in 1950. The engine is rear mounted in a roomy two-seater saloon fitted with a glass-reinforced plastic body. It drives all four wheels.

The advantages of the turbine are considerable : it is light and, having fewer moving parts than the piston engine, simple in construction. The maximum torque is developed at break-away from rest and falls off as road speed is increased. No clutch and no change-speed gear are required, as the two-shaft turbine inherently functions as a pneumatic torque converter. On the other hand, the thermal efficiency is lower than that of a piston engine, and a great deal of development work, in particular in the field of heat exchangers, has still to be done before automobile gas turbines will become a marketable proposition.

Whereas the gas turbine car more or less represents the car of the future, another interesting development has come closer to realisation : we refer to the wide adoption of

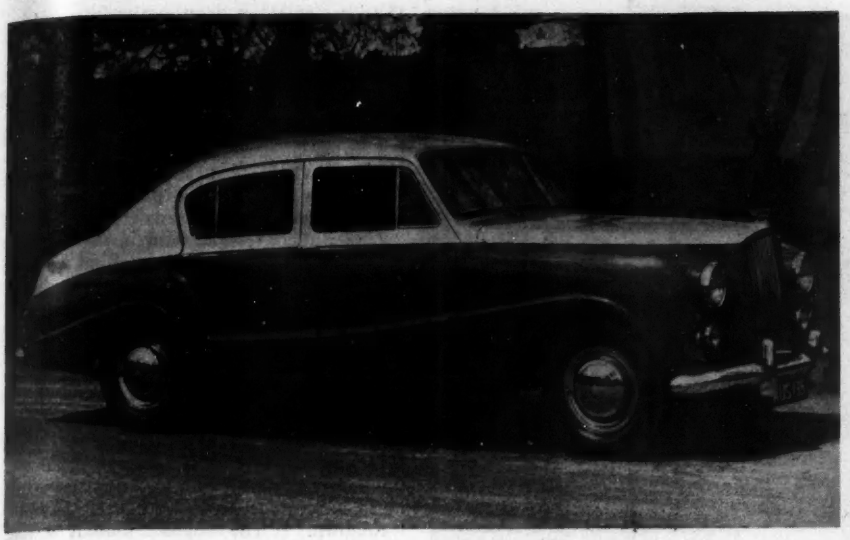


Fig. 1—The Austin "Princess IV" car with automatic transmission

automatic and semi-automatic transmission devices, which are to be seen in about twenty of the British cars on view. Transmissions adjusting themselves automatically to variable load demands have been known in this country for some time; the "Hydramatic" gearbox, first introduced by General Motors in 1939, has been built in this country under licence by Rolls-Royce, Ltd., since 1952 and fitted to Rolls-Royce and Bentley cars, has gained considerable success especially in overseas markets. Although primarily intended for the convenience of the driver, in simplifying automobile control, it has proved a strong factor in preventing engine abuse by obviating speeds below 1500 r.p.m., thus reducing the octane requirements of the engine. The "Hydramatic" transmission, however, which employs a fluid coupling and three epicyclic gear trains, is mainly suitable for powerful cars with a favourable power-to-weight ratio in which by far the greater amount of running is done inside the economic coupling range, i.e. at negligible conversion ratios.

For some time it was held that the use of hydraulic transmissions would not be justifiable in medium-sized British cars with a lower power-to-weight ratio, where the increased demand for higher torque ratios would force a converter off its economic range. The introduction, however, of the Borg-Warner transmission, now being built in this country, has caused several manufacturers to adopt this system for medium-sized cars fitted with engines of 2·5 to 3·5 litres capacity. As we have already reported in our article on the Commercial Vehicle Show, the Borg-Warner transmission is of comparatively simple design, consisting basically of a single-stage torque converter with a maximum conversion ratio of 2 : 1 and two epicyclic gear trains. It avoids appreciable hydraulic losses and therefore excessive fuel consumption by the use of an automatically controlled friction clutch, which in top gear locks the turbine runner of the converter solidly to the pump runner.

So far the Borg-Warner transmission has been adopted by Ford, Humber, Jaguar, and others as an optional extra, and it may well prove to be of considerable importance in the fight for sales abroad. Possibly it can be expected eventually to replace the preselective epicyclic gearbox with either a fluid coupling or with a centrifugal clutch, examples of which are still to be found in Armstrong-Siddeley and Daimler cars.

Another device for facilitating gear changing was introduced as early as 1952 by the Borg and Beck Company under the name of "Manumatic Control." It is suitable for almost every kind of car, utilising the normal synchromesh gearbox and final drive without any major alterations to the existing design. The "Manumatic" gear change system is not a fully automatic transmission, because the decision as to when to change gear rests entirely with the driver. In other respects, however, though not providing all the amenities of a fully automatic gear change, it facilitates the gear change by eliminating the use of the clutch pedal. The "Manumatic" and the "Newtondrive" gear change system of Standard both employ a centrifugal clutch in conjunction with a vacuum-operated withdrawal mechanism, the drive engagement being controlled by a sensitive switch housed in the top of the gear lever. The "Newtondrive" system at present is optional equipment for Standard "Ten" cars, while the "Manumatic" control is available for the smaller models of the British Motor Corporation and of Armstrong-Siddeley. In this connection it should be mentioned that the use of two-pedal control is not confined to this country, but that the French Renault rear-engine cars can also be fitted with a similar device employing the "Ferlec" control using a magnetic electric clutch. To judge from the popularity of this device, it can be concluded that the above-mentioned and other systems of two-pedal control in future will find a very much wider application.

It is doubtful whether we should mention the aim of increasing the specific output of engines as a special tendency to-day, because, in fact, this process has been going on in all automobile producing countries for a long time. It is an inevitable outcome of the progress made in engine design and of the wider availability of improved accessories as pistons, piston rings, bearings and so on. The now readily available high-octane petrol has stimulated manufacturers to use higher compression ratios with favourable results upon output and engine torque. With the exception, however, of engines for a few specialised sports cars, the average compression ratios have not been raised to more than 8·5 : 1, so that the new 100 octane fuels are not necessary and are in fact not generally recommended by the manufacturers.

Apart from these trends, there is an inclination which seems to be particularly pronounced in the British motor industry to adopt a very rigid and, as many observers believe, a rather exaggerated tendency towards rationalisation, i.e. towards the aim of production of a multiplicity of models with a minimum of differing mechanical components. Such a trend, of course, is economical from the manufacturer's point of view; but, on the other hand, it seems questionable whether it is really in the best interest of any sales organisation abroad if a quite bewildering selection of models with very similar specifications are offered and confront the customer with the difficulty of selection where very little real constructional difference exists. Many mechanical components of these cars will, of course, be either identical or at least similar, but there will still be sufficient difference in body construction, equipment and so on to make the maintenance of an adequate spare part supply a problem.

Another practice which may have some commercial value, but does not appeal to many engineers, is the fashion of offering one and the same car as a standard model, *de luxe* model and sometimes even as a sports model. As long as the *de luxe*

Fig. 2—The Standard "Vanguard" estate car

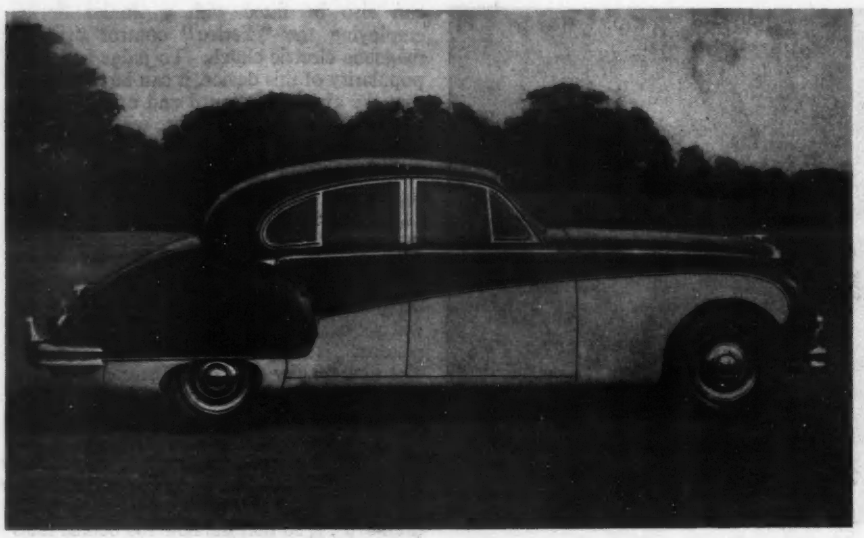


Fig. 3—The luxurious Mark VIII Jaguar saloon

model differs from the standard model only through the inclusion of some otherwise optional extras, a dual colour scheme or better upholstery, such a tendency may well be appropriate, but too often in recent years we have seen so-called *de luxe* models which have actually lost in appearance by excessive ornamentation serving only to break up otherwise clean and pleasing body lines.

The task of converting a standard model into a sports car, without any major alteration of the mechanical components, is, of course, even more difficult, and it is a matter of opinion whether it can be satisfactorily solved by such means as "hotting up" an otherwise standard engine, the addition of an overdrive gear, and so on. However, that is a matter of expediency, and only experience can show whether or not efforts made in this direction will produce adequate sales results.

These questions do not apply to the use of the same model as a station wagon, because in that case the operational conditions are the same as those of the standard model and any modifications remain confined to the body work. From the fact that more manufacturers than in recent years are showing these estate or double-purpose cars—some of them extremely well styled—it must be concluded that there is a growing demand for this type, which, incidentally, can be satisfied with comparatively simple constructional adjustments.

Generally speaking, styling at this year's show has improved, though mainly by minor alterations, and some of the latest models introduced this year by the Rootes Group and by the Ford Motor Company can be considered equal to the best Continental designs.

Turning now to a survey of the various exhibits, it is obvious that lack of space prevents us from mentioning British models which differ from those seen last year in only minor points, frequently consisting of nothing but modifications to the arrangement of instruments, lamps, radiator grilles or the addition of some new accessories.

The only new car at the various stands of the British Motor Corporation is the Austin "Princess IV," a car developed from the current A.135 "Princess" model. This car has an entirely new chassis and is fitted with a 150 h.p. 4-litre engine, a "Hydromatic" transmission, power-assisted steering and vacuum-servo assistance for the hydraulic brakes. The six-seater body, built by Vanden Plas, is a composite structure of steel and light alloy, rubber mounted on the chassis. Equipment and finish are lavish and include built-in heater and ventilator unit, hide upholstery and walnut veneered facia and woodwork. The car weighs 40 cwt and is designed for a maximum speed of about 100 m.p.h. (Fig. 1).

The popular Austin A.30 and the Morris Minor are now being fitted with a new engine, the capacity of which has been raised from 800 c.c. to 950 c.c. by increasing the cylinder bore from 58mm to 63mm while maintaining the same stroke of 76·2mm. With a compression ratio of 8·3 : 1 the output of the new engine has been raised from 28 h.p. to 34 h.p. with a 25 per cent higher torque in the medium speed range. In most other respects neither the new Austin, known as A.35, nor the Morris Minor "1000" differ greatly from their predecessors; a new radiator grille and a larger rear window have had no appreciable effect on the appearance of the Austin.

Most 2·6-litre cars of the B.M.C. are now available with the Borg-Warner automatic transmission, while the 1·5-litre cars can be supplied with the "Manumatic" control.

At the stand of Ford Motor Company, Ltd., the range of small cars represented by the "Anglia" and "Prefect" remains unchanged. The new "Consul," "Zephyr" and "Zodiac" first marketed last March, are no strangers to the general public; they offer considerable improvements over the earlier models bearing these names and, mainly by their attractive styling, have proved very successful in export markets. The Ford range has been completed by a new "Zodiac" convertible with power-operated hood and by estate cars based on the above-mentioned saloons. All six-cylinder models are now available with the Borg-Warner automatic transmission.

No major alterations are noticeable at the Vauxhall stand, but new estate cars based on the current saloon types are now available.

The Standard "Vanguard Sportsman" is externally distinguished from the normal Phase III mainly by a radiator grille, derived from the design of the old Triumph "Renown." The engine, though having the same dimensions as that of the "Vanguard," has a 13 per cent increase in output over the "Vanguard" and, with a compression ratio of 8 : 1, develops 90 h.p. at 5500 r.p.m. It is fed by two SU semi-downdraught carburettors in place of a single Solex. The smaller range of Standard cars remains unaltered, but the "Family Ten" and the "Super Ten" can now be fitted as an optional extra with the already mentioned two-pedal control.

The latest version of the Hillman "Minx," introduced in the middle of this year, shares many common parts with the Sunbeam "Rapier" and the Singer "Gazelle"; it has a pleasing appearance and provides good all-round visibility due to the large window area and a wrap-round rear window. A new addition to the range of cars made by the Rootes Group is the "Gazelle," a combination of the "Rapier" body and main components with the well-proven Singer 1·5-litre overhead camshaft engine. Externally the main recognition feature is the pleasing radiator grille, which slightly resembles that of Alfa Romeo.

As usual, the Motor Show is well stocked with luxury cars like Rolls-Royce, Bentley, Daimler and others, which, by virtue of their workmanship, reliability, responsiveness and silence enjoy a widespread international reputation. As a rule rather orthodox and restrained in appearance, and

Fig. 4—Aston Martin "Superleggera" sports car with body built by Carrozzeria Touring, Milan

probably not quite as well styled as some of the latest American and Continental models, they represent a class of their own in which mechanical perfection is taken for granted. Although these cars are being made in comparatively small numbers, based to a large extent on individual craftsmanship, their design principles change very little.

Rolls-Royce shows a power-assisted steering unit on the "Silver Wraith" to facilitate the handling of this long-wheelbase car, particularly at slow speed. The degree of power assistance varies automatically with the load and, at normal speed, assistance is approximately 50 per cent of the power required. Should the wheel be against an obstruction, such as a kerb, a valve automatically cuts out the servo.

The Daimler Motor Company, after twenty years of experimenting with "popular" priced models, appears to be reverting to its original policy of making only high-priced cars, the Lanchester "Sprite" being abandoned.

Among the cars which never fail to attract a great deal of public attention are those of Jaguar Motors, Ltd., the latest addition to the range of the company being a luxury version of the Mk. VII to be known as Mk. VIII (Fig. 3). Mechanically almost identical with the former type the car can be supplied either with a four-speed synchromesh gearbox, optionally supplemented by an overdrive gearbox, or with the Borg-Warner transmission. An interesting complement to this transmission, developed by the Jaguar company, allows the driver to retain the intermediate gear ratio by an over-riding control in form of an electric

Fig. 5—Rear suspension of the 1100 c.c. Lotus "Le Mans" sports/racing car

switch which operates a hydraulic lock in the gearbox.

Examples of the more advanced school of automobile engineering are almost entirely confined to those British cars which are made in small quantities only. We mention among these cars the Lagonda and Aston Martin, both made by the David Brown group of companies. An interesting example of a particularly well-styled sports car is the Aston Martin "Superleggera," having an Aston Martin D.B. 2/4 chassis with a 150 h.p., 3-litre engine and a very light aluminium body designed and built by Carozzeria Touring of Milan, one of the leading Italian coachbuilders. The model (Fig. 4.), designed for export only, is not available in this country.

The Frazer-Nash "Continental," a sports car made in very small numbers only, is characterised by such features as a De Dion rear axle layout and a 2·5-litre Vee-eight engine. The latter has been derived from the German B.M.W. engine by reducing the bore of the cylinder liners to bring the car within the 2·5-litre limit for competition purposes.

Fig. 6—Berkeley front-wheel-drive, two-seater sports car with glass-fibre plastic body

The Lotus Engineering Company, Ltd., shows three examples of racing and sports cars, one being the "Le Mans," a car of the type which won the 750–1100 c.c. class, in the famous Le Mans twenty-four-hours' race. The "Le Mans" has a space type tubular chassis frame suitably reinforced by the floor and the propeller-shaft tunnel. The 1100 c.c. "Climax" engine of 72·4mm bore and 66·6mm stroke has a compression ratio of 9·8 : 1 and develops 75 h.p. at 6250 r.p.m. It is mounted tilted sideways about 10 deg. from the vertical, and the torque is transmitted via a single dry plate clutch and a four-speed gearbox to the final drive casing which is rigidly mounted on the frame structure. Universally jointed half shafts transmit the torque to the road wheels which are carried by a De Dion tube, the whole system being located by coil springs in connection with parallel trailing arms and a Panhard rod (see Fig. 5). Hydraulic disc brakes are employed at the front as well as at the rear, the latter ones being arranged inboards, i.e. on either side of the final drive casing. The well streamlined car weighs less than 8 cwt, and maintenance is greatly facilitated by panelling which can be easily detached.

A new British car at this year's show is the two-seater sports car of Berkeley Coachwork, Ltd., a firm which has been mainly engaged in building caravans. The Berkeley belongs to the category of miniature cars and represents a type which in this country has so far been looked at with a certain amount of apprehension, but has recently become very popular on the Continent. The most interesting feature of the car is the stressed-skin body and frame. This is a rigid structure, using a combination of resin-bonded moulded glass fibre with aluminium alloy bulkheads and cross members moulded in, to form an integral structure of a favourable strength-to-weight ratio. It is powered by a 322 c.c. British Anzani air-cooled, twin-cylinder, two-stroke engine which develops 15 h.p. at 5000 r.p.m. The engine is mounted transversely in the body structure and transmits the torque by a roller chain to a three-speed gearbox which is attached to the crankcase. The front road wheels are connected by universally jointed half-shafts to a differential driven by an exposed chain. All wheels are independently sprung, the front wheels by wishbones of unequal length with Girling combined coil spring and damper units, and at the rear by similar units in combination with swing axles. Hydraulic brakes, with two leading shoes at the front and leading and trailing shoes at the rear, are employed, and are

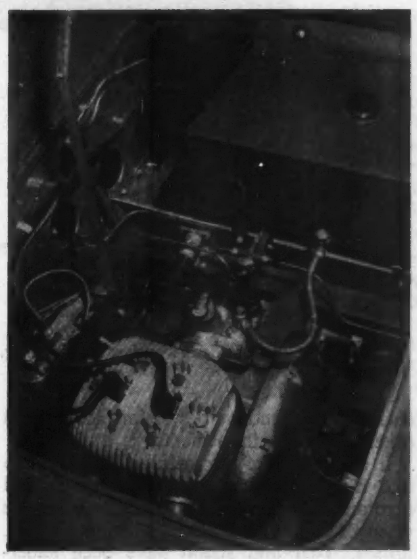


Fig. 7—Air cooled engine transmission unit for Berkeley front-wheel-drive car

claimed to give decelerations of almost 1 g. at a maximum pedal pressure of 70 lb. The car has a wheelbase of 5ft 10in, a track of 3ft 8in, and weighs only 5¾ cwt ; it has clean and pleasing lines and is said to be capable of a maximum speed of 70 m.p.h. It will be interesting to watch the reaction of the public towards this interesting little car (Figs. 6 & 7), the design of which embodies some sound engineering principles.

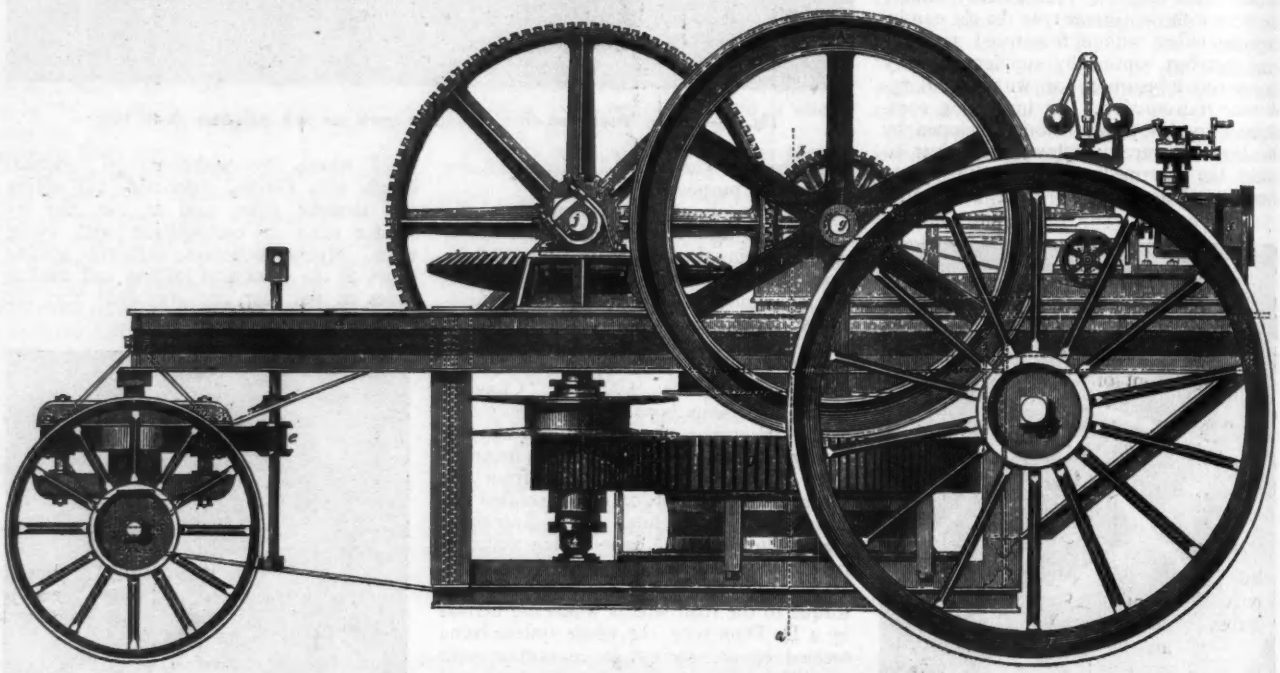
(*To be continued*)

Power for Ploughing

One hundred years ago, John Fowler first successfully employed steam power for ploughing or "turning over the soil." In a lecture, delivered to the Institution of British Agricultural Engineers last Tuesday, Mr. D. R. Bomford recalled Fowler's work. For more than sixty years, steam power had an important place in mechanised agriculture. Some of the developments are reviewed here.

PLOUGHING is an ancient art. In recent years there have been suggestions at different times that other methods of "turning the soil" would be satisfactory, but, generally, ploughing continues to be essential in modern methods of agriculture. Last week, the fourth World Ploughing Contest was held at Shillingford, Berkshire. It was the first time that the contest has taken place in this country, and, combined with it, there was a comprehensive display of agricultural machinery. Some of the competitors taking part in this World Contest used horse-drawn ploughs; others were working tractor trailed and mounted ploughs. The art of ploughing may not have altered much for centuries, but over the past hundred years engineers have brought about great changes in the motive power for ploughs and other cultivating implements.

In some parts of the world, it is possible to find horses or oxen drawing a plough, and here and there steam ploughing may still be discovered. But in the last twenty years, horses, oxen and steam have been superseded by internal combustion engine power. Wheeled and crawler tractors, equipped with power take-off and hydraulic lift systems, have effected a striking transformation in the practice of agriculture. Before then, however, for several decades, the utilisation of steam power in agriculture made a significant contribution, a contribution which may, sometimes, be too readily forgotten!



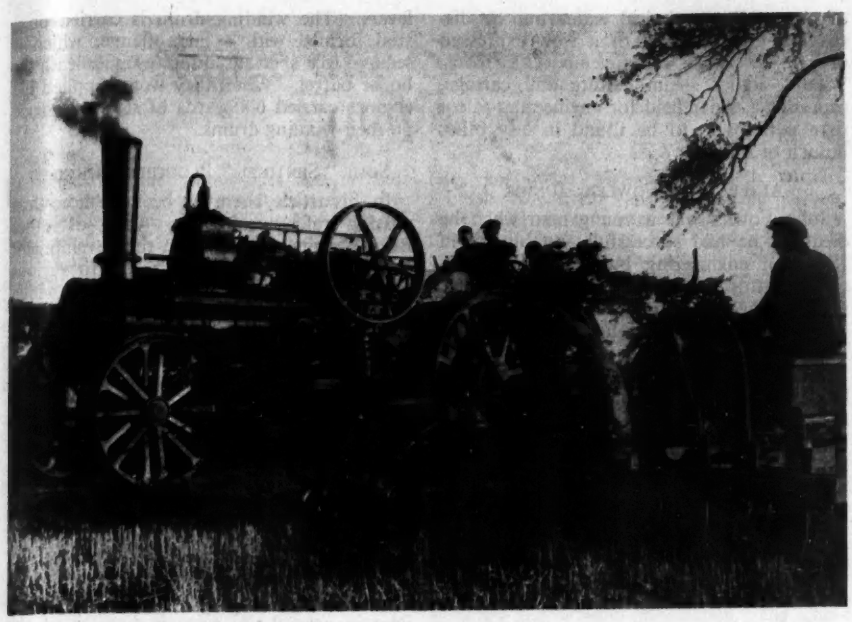
One of Fowler's machines for ploughing. The boiler was "mounted on wheels by itself, a flexible pipe conducting the steam to the cylinder"

The Work of John Fowler

In the latter half of last century, and in the first thirty years of the present one, there were several British engineering firms which were distinguished for their production of steam portable and traction engines for agricultural use. Among them, one of the pioneers was undoubtedly John Fowler, Junior, of London and Leeds, whose work has been most appropriately recalled in a memorial lecture, which was delivered on Tuesday, at a meeting of the Institution of British Agricultural Engineers, by its president, Mr. D. R. Bomford. Exactly one hundred years ago, in 1856, John Fowler, who was then thirty, and who had earlier intended to take up a railway engineering career, took part in a competition, organised by the Royal Agricultural Society, for "the steam cultivator which shall in the most efficient manner turn over the soil and be an economical substitute for the plough or the spade." It was not the first competition of its kind, for in the preceding year, the Royal Agricultural Society had organised one; then, there were three competitors, none of whom fulfilled the conditions, but John Fowler was not among them. Up till that time he had concentrated on the use of steam power for mole draining, rather than for actually "turning over the soil." No doubt the measure of success which he achieved with his mole drainer urged Fowler to go on to develop his equipment to become an "economical substitute" for the ploughs that then existed.

For some years prior to 1856, as Mr. Bomford explained in his lecture, John Fowler had frequently consulted William Worby, who was the "manager and implement expert" at the Ransome (subsequently Ransomes, Sims and Jefferies, Ltd.) factory at Ipswich. By the middle of January, 1856, Mr. Bomford said, Fowler and Worby had accepted the possibility of cultivation by steam and were discussing methods of reversing ploughs at the ends of furrows in such a way as to lay all the furrows in the same direction. Fowler had discussed the problem with David Greig, a farmer, and they conceived the idea of the right and left-handed balanced plough which was destined to be used for cable ploughing for the succeeding eighty years. In general the design was that of a frame mounted as a "see-saw" on a two-wheeled axle. One side of the "see-saw" carried right-hand plough bodies, the other side left-hand. In use the frame was never turned round, but always hauled to and fro on the rope, with one or other of the ends of the "see-saw" down, with its plough bodies engaging the soil. To make this possible on a low axle, it was necessary to make the frame with a bend across its middle so that when the two ends were level they were rather higher than the middle where the axle supported the frame. By moving the plough in one direction with the right-hand bodies engaged, and in the other direction with the left-hand bodies engaged, it would be possible to turn all furrows in the same direction. At their mid-January discussion in 1856 Fowler explained the idea to Worby. It seemed to him to have greater possibilities than the turn-wrest principle he had been planning, and Worby undertook to investigate the possibilities of the balanced plough.

The outcome of these deliberations was that John Fowler gave Worby instructions to build a set of steam ploughing tackle with a Ransomes and Sims' portable engine driving a stationary double-drummed windlass and hauling a balanced plough. It was an eventful order, resulting in the first successful application of mechanical power to land cultivation. When we remember the severe limitations of manufacturing facilities, and indeed of communications of those times, we may well wonder at the speed at which these men worked! The order was given on January 30, 1856. On April 10, 1856, the



One of a pair of Fowler ploughing engines constructed about 1918. The engines, whose nominal horsepower is 14, are still being worked. The implement shown here is a cultivator or "scarifier"

machinery was working at Nacton, near Ipswich, and ploughed an acre in an hour. Fowler's father, John Fowler, senior, and J. A. Ransome were both present on this occasion. The arrangement was similar to that of Fowler's steam-draining machinery, and included a portable engine with a belt drive to a stationary anchored windlass set in a corner of the field to be ploughed. The windlass had two drums on the same horizontal axis. The windlass was set so that the direction of the ropes as they left the drums was along one of the headlands of the ploughing. There were three pulleys on separate anchors, one being anchored immediately in front of the windlass. This was a permanent fixture during the whole ploughing process. The other two were temporarily anchored and were moved along opposite headlands as ploughing proceeded. One rope from the windlass was led round the temporarily anchored pulley on the same headland as the windlass and thence across the field to the plough. The other rope was led from the windlass round the permanent pulley in front of the windlass, diagonally across the field to the pulley on the opposite headland and round this and back to the plough where it was fixed. By this means it was possible to work the balanced plough in both directions. The plough was steered by a man who walked beside it with a long pole used as a lever.

An idea of another "machine for ploughing land" patented by Fowler may be gained from the engraving on page 556, which is reproduced from THE ENGINEER of September 12, 1856. In our description of this machine we explained that the front wheels had a locking motion to which was attached a toothed arc, working with a pinion, and having at its upper end a handle for steering. At one end of the crankshaft there was a flywheel, and at the other end a pinion (*h*), driving the toothed wheel (*i*) on the axis (*j*). On the axis (*l*) there was a drum, which was used for moving the machine from place to place, "for which purpose one end of a rope was made fast to an anchor placed in the direction in which it was desired to move the machine, the other end of the rope being passed round the drum." On the axis (*l*) there was a pinion for driving a toothed wheel on an upright axis, to which was keyed a capstan. The rope for hauling the plough "passed round" the capstan. Our description of this apparatus a hundred years ago ended by pointing out that the boiler for supplying the machine with steam was "mounted on wheels by itself." It was coupled to the machine by a flexible pipe, which conducted the steam to the cylinder (*f*).

The possibility of steam ploughing was proved, though the digging of holes for the successive positions of anchors on both headlands presented a problem. Fowler realised that if his machine required the assistance of too much hand-work, its claim to have lowered costs was unlikely to be established. On that account he made movable anchor carriages in time to compete for the Royal Agricultural Society's prize in the summer of 1856. The prize, incidentally, was £500, compared with £200 offered a year earlier. The anchor carriages were carts full of earth, each cart having four disc wheels and wooden rollers to prevent the disc wheels from sinking too far into the ground. Whilst only rolling resistance was offered to a forward movement of the cart, cutting of the disc wheels into the ground created considerable resistance to any lateral movement. A sheave for the rope was provided underneath the frame of each cart. A cart anchor was placed on each headland at the side of the field on which ploughing would start, and the anchors were directed so that they would roll along the headlands. The portable engine and belt-driven windlass were set with the windlass anchored at the middle of the opposite side of the field, this being the side on which ploughing would finish. The windlass carried two drums on separate vertical axes. The rope from one drum was taken across the field to one cart anchor, round the sheave and to the plough. Similarly the rope from the other drum was taken round the sheave on the other disc anchor and to the plough where both ropes were fixed. The cart anchors were moved along the headlands by ropes which led, one from each anchor, along the opposite headlands. Each rope passed round an anchored pulley at the end of the side of the field on which the windlass stood and was led to the windlass. It seems likely that there was a mechanism on the windlass which enabled the power of the engine to be used to haul on these ropes and move the anchors into line with the direction of haulage of the plough as work progressed. But, as Mr. Bomford commented in his lecture last Tuesday, in this arrangement there was a mechanical heresy of which Fowler must have been aware! It assumed that the reaction to the tension of the ropes was in line with the lateral resistance offered by the anchors. The reaction to this tension was actually along a line bisecting the angle between the rope leading on to the sheave on each anchor and the rope leading off it. Fowler must have decided to risk the misalignment of this reaction, but a later arrangement embodied a correction of it. It seems, Mr. Bomford said, that the risk he took was to some extent justified because his first arrangement of the disc-wheeled cart anchors was entered for the £500 prize offered by the Royal Agricultural Society at its meeting at Chelmsford in 1856. During the meeting Fowler's plough was working at Romford and turning four furrows at a time. Decision on its merits by the judges was postponed for further trial on August 14th and 15th. A few days before the trial an acre and sixteen perches had been ploughed in an hour. The judges were apparently satisfied with the quality of the work, but not with its economy. They estimated the cost of ploughing by Fowler's tackle to be 7s. 2¼d. an acre and that the cost of ploughing the land with horses might have been 7s. an acre! Because of this no award was made (a matter on which this journal expressed some forthright opinions 100 years ago!). But although Fowler failed in the year 1856 to secure the prize offered, he succeeded in demonstrating that ploughing by steam had passed the stage of theoretical development and had established itself as an applied process with an assured future.

It was also in 1856 that Fowler filed a patent on the double-engined system of steam ploughing which was destined to become the only acceptable means of mechanical cultivation for more than sixty years. This consisted of two engines each with a built-on drum carrying rope. The engines moved along opposite headlands and pulled the plough alternately between them by means of their ropes. Fowler undoubtedly kept in mind the potentialities of the double-engined system, but he, nevertheless, continued, for the next year or two, the development of ploughing tackle based on the use of a single engine. At the Royal Agricultural Society's meeting at Salisbury, in 1857, he again demonstrated a single-engine set, but, once more, the prize of £500 was withheld on the score that the "economy of steam ploughing still remained unproved." But in the same year the Highland Agricultural Society awarded Fowler a prize of £200 for "the practical application of steam or water power to the ploughing or digging of land."

At length, the value of Fowler's pioneering work received recognition by the Royal Agricultural Society. In the 1858 competition, Fowler worked a ploughing tackle which consisted of a "self-moving" engine on one headland and a disc anchor with a rope haulage mechanism on the other. There were three other entries: Boydell's traction engine, which ploughed by direct haulage; Rickett's locomotive engine to drive revolving cultivators, and J. and F. Howard's stationary engine. The judges estimated that the cost of ploughing with Fowler's equipment was 5s. 6d. per acre, and that, with horses, the cost would have been

10s. The final decision of the judges was delayed until the autumn of 1858, but ultimately John Fowler was awarded the £500 prize, by which time, it is recorded, he had spent about £5000 on his experimental work.

During the following six years, John Fowler continued his experimental work with characteristic vigour. Many different systems of cultivation by rope haulage were developed and used. In 1863 the Royal Agricultural Society held its annual meeting at Worcester. There Fowler demonstrated a double-engined set of steam ploughing tackle. Each engine had one drum, carrying a full length of rope and mounted on vertical axis studs underneath the boiler. The drums were fitted with rope coiling gears. The engines propelled themselves and were steered by a man on the engine. This set demonstrated all the fundamental principles of the sets which for the next half-century were to maintain the prestige of steam ploughing as the only economical and efficient means of mechanical cultivation. Steam ploughing was at last firmly established, but still Fowler was not satisfied. In 1859 he had filed a patent on a device known as the clip drum. In this the flanges of a sheave were made in short sections. These sections were independently hinged in such a way that the radial pressure of a rope drawn tight round the sheave caused each pair of opposed sections to converge and grip the rope. This clip drum or sheave took the place of the rope-carrying drum and was rotated by the power of the engine. At the Royal Agricultural Society's Newcastle meeting in 1864 Fowler exhibited a double-engined set with clip drums. Each engine was rated at 7 nominal horsepower and the set, operating a four-furrow balanced plough, worked eight acres in ten hours. The working pressure of the engines was 100 lb per square inch and the coal consumption, it has been stated, was no higher than 188 lb per acre. In his lecture, Mr. Bomford described the Newcastle competition as Fowler's greatest achievement, but it was his last, for he died on December 4, 1864, following an accident in the hunting field. He was only thirty-eight, but in a few years of outstanding technical endeavour he discovered the fulfilment of a view expressed in THE ENGINEER of November 21, 1856: "Land, under steam culture and cartage, promises a wider field for engineering talent than perhaps is to be found in any other branch of industry."

AFTER JOHN FOWLER, JUNIOR

John Fowler was a young man when he died but he had successfully established in Leeds an engineering business which continues to this day, though it no longer builds steam ploughing engines. At the beginning, Fowler's engines and ploughs were made by Ransomes, Sims and Jefferies, Ltd., at Ipswich, and some of his engines were also built by Clayton and Shuttleworth, Ltd., Robert Stephenson and Co., and at the Airedale works, Leeds, of Kitson and Co., Ltd. For sixty years after his death, the firm which John Fowler established continued with the production of steam ploughing tackle. During those years, boiler pressures were increased, cast iron parts were replaced by steel, wheel diameters were increased, and the single-cylinder engines gave place to compound engines with balanced crankshafts and high piston speeds. But fundamentally the design remained the same as that of the engines demonstrated by Fowler in 1864.

Although steam cultivation is now, as has been said so often, a thing of the past, there are still in existence, and in fairly regular work, some sets of steam ploughing engines. One such example is illustrated by the photograph which is reproduced on page 557. It shows one of a pair of 14 h.p. Fowler engines which are owned and operated by T. T. Boughton and Sons, Ltd., Amersham. These engines were built towards the end of the first world war, for the Government, the intention being to supply them to agricultural machinery contractors on a deferred payment scheme. Their boilers were constructed in accordance with locomotive practice, the working pressure being 180 lb per square inch. The road gears are operated by a safety clutch, and the engines were designed to incorporate two sets of ploughing speed gears, both being arranged on an upright shaft and operated by separate clutch levers. The winding drum is carried on a stud formed with a large flange, which is secured to a special mounting underneath the boiler barrel. When they were supplied the engines carried 600 yards of steel wire rope on their winding drums.

This "lightweight" engine is one of a pair built for steam ploughing in the 1920s. The cable drum was mounted vertically between the front and back wheels

SOME "SENTINEL" PLOUGHING ENGINES

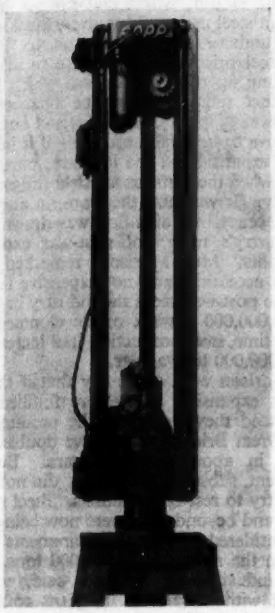
In this article, there has been no more than passing reference to the work of other British engineering firms in the development of steam power for agriculture. In various parts of the country some of the engines which they produced can still be found. Recently, however, we were told about an unusual "improvisation" which, in its day, gave useful service in the business of steam cultivation. In the mid-1920s, Bomford Brothers, Ltd., Pitchill, Evesham, a firm of engineers and agricultural contractors, wanted some ploughing engines that were a good deal lighter on the ground than any then available. The firm decided, therefore, to build a pair of ploughing engines incorporating "Sentinel" engines and boilers which were obtained from the London and North Eastern Railway. Mr. P. W. Lester, who is now the managing director of the firm, was mainly responsible for the work.

Mr. Lester tells us that the engines—one of which is illustrated herewith—were built with the aid of "rough sketches" only, and that at the time the works had only oxy-acetylene cutting equipment and a rather limited range of machine tools! The Sentinel engine was mounted on a superstructure approximately halfway along the main frame which was constructed in the Pitchill works. The drive from the engine to the layshaft was taken by 2in duplex chain, and then through dog clutches, again by duplex chain, to the back wheels. The dog clutches, Mr. Lester says, were fitted on each side, which enabled the drive to the back wheels to be independent. The clutches, incidentally, were machined from steel billets and the rear driving sprockets were made from a 2½in square bar, and then mounted to the rear wheels. The cable drum was placed just behind the front wheels, in a vertical position in the centre of the main frame, the cable being led to the rear of the frame, running round a 2ft 6in diameter guide pulley, and then coming forward again round another 2ft 6in pulley. This arrangement permitted the cable to be paid out between the front and the back wheels. By mounting the cable drum vertically, Mr. Lester says, it was unnecessary to provide a coiling gear. Unfortunately, Bomford Brothers, Ltd., cannot now remember, and there is no record of, the horsepower or the actual weight of these home-made engines. Nevertheless, when they were built they performed satisfactorily work for which in later years crawler tractors came to be generally employed.

CIVIL ENGINEERING FIRM'S LABORATORY.—We have received from George Wimpey and Co., Ltd., Hammersmith Grove, London, W.6, a book which describes the activities of that firm's central laboratory. Apart from the special needs of the various contracting works being undertaken by the Wimpey organisation, the laboratory has carried out a considerable volume of work independently for consulting engineers and architects. The laboratory's work embraces investigations in the following subjects: soil mechanics (including site investigation and foundation engineering), concrete, building, asphalt and tarmacadam, metallurgy, plant and structural engineering. There is a library and information service. One interesting piece of work recently carried out was the construction of a hydraulic model of the Volta River. The book may be obtained on application to the firm's public relations officer.

Echo Range and Sounding Fishing Equipment

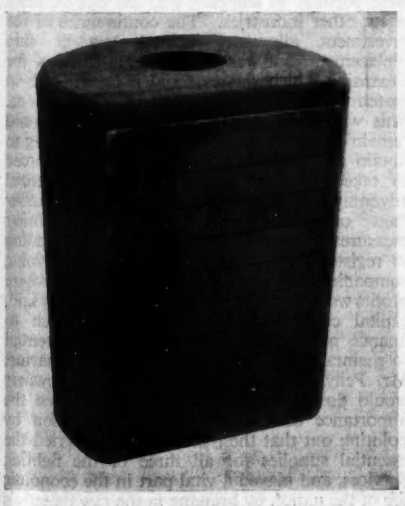
IT is nearly four years since Kelvin and Hughes (Marine), Ltd., introduced the "Echo Whale Finder," described in THE ENGINEER of December 5, 1952, to assist in the tracking of whales; in the meantime the company has been engaged in the development of equipment to help fishermen. Research in this direction has resulted in the production of the "Fisherman's Asdic," a prototype of which we were able to inspect last week. Since a fish echo was first noted on an echo sounder work has gone forward



Transducer hoist/train assembly

to perfect equipment which will assist in the search for fish and so have a considerable effect upon the economics of the industry. Although improvements in technique have resulted in better performance of echo sounders, it was considered that horizontal echo ranging would prove a valuable aid in the search for fish shoals by obtaining earlier detection by means of echo ranging or asdic.

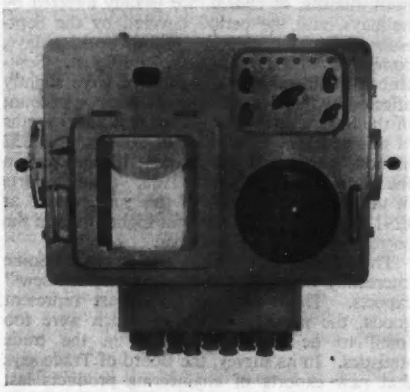
Several years of experimenting resulted in the production of a piece of equipment, six sets of which went to sea for three years for practical tests, on board Fisheries Research vessels, Scottish ring-netters and Norwegian fishing vessels. Trials were carried out off the West Coast of Scotland, and the East Coast of England, and also in the English Channel and in Norwegian waters. Data yielded by the investigations have been incorporated in the production model of what is known as "Fisherman's Asdic," and which is a fully automatic high-power combined echo-ranging and echo-sounding piece of equipment specifically intended for pelagic fish shoal detection.



Transducer unit

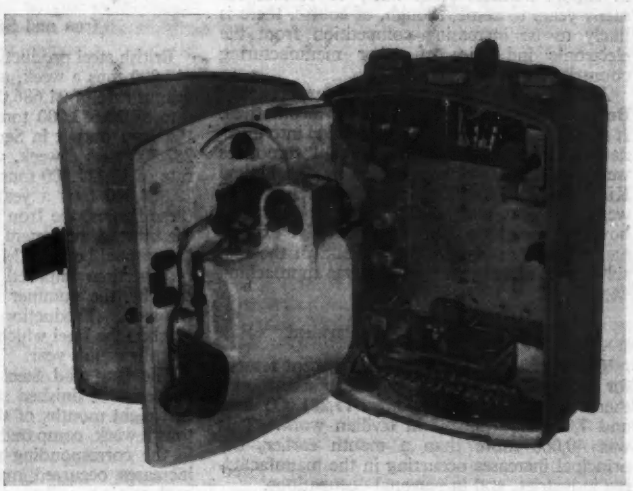
The gear, which has a maximum operating range of 2000 yards and a control system providing for automatic step training, consists of three units, namely, hull unit, wheelhouse control unit and rotary converter. Transducer training and the raise-lower mechanisms are arranged for remote control and provision made for the rapid retraction of the transducer into the hull fairing. Automatic sector searching is incorporated and the equipment operates with chemical recording and/or audio presentation. The echo-ranging transducer has a frequency of 50 c/s with a fixed downward tilt of 5 deg. and has vertical and horizontal beam angles of 10 deg., while the echo-sounding transducer has the same frequency and beam angles of 22 deg. transversely and 17 deg. in the direction of search. An electric motor and a chain drive operate the retracting mechanism, which is fitted with limit switches at upper and lower limits of travel and has dynamic braking of the motor at the limits set. The travel is approximately 2ft and the times for housing and lowering the transducer are seven seconds and five seconds respectively. The inboard assembly of the hoisting and training is enclosed in a splashproof housing. Our illustrations show the transducer hoist train, the transducer and the wheelhouse control unit. The latter is designed for vertical mounting and incorporates controls for both hand and autostep training, the training arc being 170 deg. on either bow, leaving a small dead area astern. There are three paper speeds for each range scale and provision is made for running the recorder with the paper stopped so that the recorder may be used for initiating transmissions, without consumption of paper, when the listening channel is being used for searching. A high-gain amplifier with reverberation gain control is fitted and the transmitter, which contains four valves, gives 10^6 and 10^7 pulses per second, the long pulse being for echo-ranging only. The pulsed power output is approximately 1kW and there is a heterodyne circuit for the loudspeaker. The rotary converter is a governed d.c. motor with permanent magnet alternator field and is available for 24V or 110V supply.

Also displayed with the "Fisherman's Asdic" were two new "Fishmaster" echo sounders, an example of which we illustrate, the standard fishing equipment "M.S.28," and the deep-sea fishing equipment "M.S.29." Each provides for clear open fish records on moist or dry paper, and for three paper speeds, while a continuous phasing device extends the depth range of four times the basic scale and enables the depth setting to be selected anywhere between the scale limits. There is a choice of four basic scales, between 0 to 480 fathoms or 0 to 880m, in each recorder, and three transmission pulse lengths, while the hysteresis recorder motor, developed by Kelvin and Hughes (Marine), Ltd., has no brushes to replace, no armature to burn out, is impossible to overload, operates on 115V alternating current, and has a rotational speed of 3000 r.p.m. There is a single magneto-striction bar transducer polarised by permanent magnets which functions both as a transmitter and receiver and has a resonant frequency in water of 30 kc/s. For use with the "M.S.29" echo sounders there are available two cathode-ray tube indicators or



Wheelhouse control unit for Fisherman's Asdic, showing recorder chart and training gear control

scale expanders. The 3in pattern is small and compact and suitable for small vessels, while the 5in model is larger and incorporates additional controls.



"MS. 28/29" echo sounder "Fishmaster"

Technical Reports

Oxidation Resistant Silicon Aluminium Steels. By E. A. Brandes, B.Sc., A.R.C.S., F.I.M. Fulmer Research Institute, Ltd., Stoke Poges, Bucks. Price 10s. 6d.—Tests have shown that steels containing 2–3 per cent silicon with 0·5–1 per cent aluminium, while no better in corrosion resistance than mild steel, are comparable in oxidation resistance up to 900 deg. Cent. with 18 : 8 stainless steel. They are adequately ductile for cold working and benefit greatly from aluminium coating: scaling resistance in moisture-laden flue gases appears highly favourable. The absence of strategic elements in these alloys is noteworthy.

Application of Spring Strips to Instrument Design. Notes on Applied Science No. 15. H.M. Stationery Office. Price 2s.—The use of spring strips of tempered steel or other material in instrument design is described and illustrated extensively. Pivots and parallel motions, amplifiers and adjusting devices, are among the varied and ingenious mechanisms recorded. Details are given of methods of mounting spring strips.

Industrial and Labour Notes

Overseas Trade

The Board of Trade has issued some provisional trade figures for September. They show that the value of exports from the United Kingdom was £222,200,000, which was £31,000,000 less than in August. Exports in both months, of course, are usually affected by holidays, and the period covered by the September figures included twenty-four working days, compared with twenty-seven in August. September shipments, the Board says, were slightly affected by the requisitioning of ships on account of the Suez emergency. In the first nine months of this year, the total value of exports, at £2332 million, was nearly 10 per cent higher than in the comparable period of 1955. Total imports in the first nine months of this year, valued at £2917 million, were 1 per cent higher than in the corresponding period last year.

The Board of Trade has also published some interesting details about this country's "new" exports. These for the most part represent goods, the prewar exports of which were too small to be shown separately in the trade statistics. In its survey, the Board of Trade says that new exports of engineering products last year were valued at £30,000,000, and were 46 per cent higher than in 1953. Among the most noteworthy achievements in this field has been the post-war growth of exports of radio communication and navigational aid and radar equipment; the value of these rose from £2,300,600 in 1948 to over £12,000,000 last year, and this year's figures show a further substantial increase. The Board of Trade points out that the wartime needs of the Forces for radio communication equipment led to the rapid expansion of what was before the war a small specialist industry. Production for military needs also led to the standardisation of valves and parts. The Board goes on to say that in this, as in some of the other new fields, excellent opportunities in export markets seem likely to remain for many years to come, though, of course, there is likely to be increasing competition from the electronic industries of other manufacturing countries.

Among other new engineering exports, the Board of Trade mentions diesel locomotives. It says that although these had entered into international trade before the war, diesel locomotives were not at that time exported by the United Kingdom, and, indeed, in 1951, exports of them were only just over £1,000,000. By last year, however, the value of diesel locomotive exports had reached nearly £8,000,000, and in the first six months of this year the value was approaching £6,000,000.

Employment and Unemployment

The Ministry of Labour's employment returns for August show that at the end of the month there were 23,095,000 people (15,281,000 men and 7,814,000 women) in civilian work. This was 40,000 more than a month earlier, the principal increases occurring in the manufacturing industries, and in seasonal occupations.

In the country's basic industries, there were 4,022,000 people employed in August. This indicated no significant change, although there was a small increase of 1000 in the coal mining labour force. At the end of August, the number of wage earners on colliery books was 703,000, compared with 702,000 a year earlier. In the manufacturing industries, there was an increase of 9000 in the number employed in the "engineering, metal goods and precision instruments" group, bringing the total to 2,789,000, compared with 2,776,000 at the end of August last year. The labour force of all the manufacturing industries at the end of August was 9,231,000, which was 26,000 fewer than a year earlier.

The latest unemployment figures show the situation on September 17th, when 247,640 people were registered as out of work, compared with 266,541 on August 13th. The September figure, it is estimated, represented 1·1 per cent of the total number of employees. It included 85,000 people who had been out of work for more than eight weeks. The Ministry of Labour says that, in the four weeks ended August 22nd, the employment exchanges in Great Britain filled 176,000 vacancies. The number of vacancies notified to the exchanges, but unfilled on August 22nd, was 361,000, which was 87,000 fewer than a year earlier. Other information given by the Ministry is that, in the week ended August 25th, there were 1,375,000 workers on overtime in manufacturing establishments, which was 185,000 fewer than a year previously. In the same week, the number working short time was 112,000, or 58,000 more than in the comparable week of last year.

European Free Trade Area

The far-reaching consequences for British industry of the European proposals for a common market and customs union were discussed last week by the grand council of the Federation of British Industries. The discussion is to be resumed at a special meeting of the council on October 31st after which the F.B.I. will report the results to the Government.

As we noted in a leading article last week, the six European countries concerned are now taking steps to create a common market, and the British Government has stated that it is considering the association of this country with the common market in the limited form of joining a partial free trade area. The question before British industry is, therefore, whether in principle it is in favour of or opposed to the United Kingdom going ahead with negotiations on these lines. The Federation of British Industries said, after its grand council meeting last week, that the Government had asked it to report on the matter "by early October." But a postponement of the report has now been agreed upon to provide opportunity for further discussion by individual industries.

Iron and Steel Production

British steel production in September averaged 417,000 tons a week, and was thus at an annual output rate of 21,686,000 tons, compared with a rate of 20,683,000 tons in September last year. Pig iron output in September, at an average of 252,500 tons a week, was running at an annual rate of 13,131,000 tons, compared with a rate of 12,804,000 tons a year earlier. In announcing these figures, the Iron and Steel Board says that the upward movement in production, which was interrupted between May and August by the ban on overtime imposed by maintenance workers and by the summer holidays, has now been resumed. Production has not, however, yet reached the level which was attained in the early months of this year.

The Iron and Steel Board also reports that deliveries of finished steel to home users in the first eight months of this year averaged 270,500 tons a week, compared with 250,400 tons a week in the corresponding period of last year. The increases occurred mainly in deliveries to the coal mining, railways and rolling stock, shipbuilding, constructional, and general engineering groups, all of which, of course, are principally concerned with the production of capital goods. There was a decline in steel deliveries to the motor, cycle and aircraft group of industries. Imports of finished steel in the first eight months of this year, the Board adds, were appreciably higher than in the corresponding period of 1955 They are now declining, however, and are likely to continue at a substantially lower level than last year. Moreover, the make-up of steel imports has changed; imports of plates and sections have increased, while those of sheet and tinplate have fallen well below last year's levels.

Steel Prices

Reference to the price of British steel was made by Mr. R. P. Morison, Q.C., the independent chairman of the British Iron and Steel Federation, in a speech, last Saturday, to the Newport and District Metallurgical Society. He said that in this country, steel prices had been, and were, low in comparison with other steel prices throughout the world, and, in general, they had remained stable. In Britain, steel was supplied at a lower price than anywhere else in the world, with the exception of Australia and, possibly, India. The advantage to the steel-using industries, compared with their competitors in other countries, had been estimated to be, on average, about 10 per cent. The aim must be to preserve that benefit as far as possible.

But, Mr. Morison continued, it must not be forgotten that for some months the steel industry had carried large increases in the cost of coal, freight and labour, which had not so far been reflected in steel prices. Moreover, there was the further fundamental question as to whether present steel prices were adequate to allow for the building up of reserves from which further development must, in part, be financed. The present level of prices, Mr. Morison suggested, might prove to be a false economy if it inhibited a proper expansion of the industry, particularly at a time when the demand for steel still exceeded the supply. It was not, therefore, in any mood of complacency that attention was drawn to the steel industry's record of post-war expansion. Steel plants, Mr. Morison remarked, were expensive necessities and not expensive luxuries, and in the post-war years the industry had spent about £1,000,000 a week on development. At the same time, steel production had increased by nearly 1,000,000 tons a year.

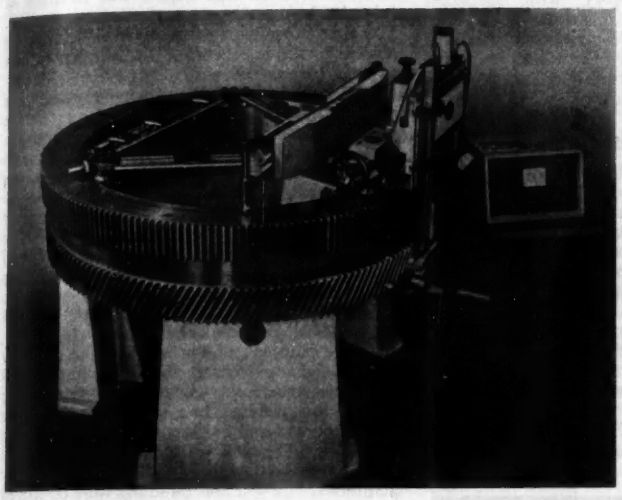
Mr. Morison went on to say that if the steel industry's expansion plans were fulfilled, as it was expected they would be, the production of steel in Great Britain would have doubled since the war in about thirteen years. But that achievement, substantial as it was, did not entitle the industry to rest on its laurels. Steel requirements in and beyond 1962 were now being carefully considered. Those requirements might well be in the region of 28,000,000 tons a year, and the industry, Mr. Morison said, was well advanced with certain of its plans to meet a demand of that order.

British Shipping

At the annual dinner of the Chamber of Shipping, held on Thursday of last week, Mr. Kenneth R. Pelly, the president, in replying to the toast of "British Shipping," proposed by General Sir Gerald Templer, mentioned that it was only in a crisis that the public realised the value of shipping. Our strength as a maritime power, he went on, was diminishing in relation to the rest of the world since the economic forces exerted by flag discrimination, penal taxation and flags of convenience created problems which adversely affected our shipping operations. These problems, he emphasised, were peculiar to shipping and did not similarly affect other industries. The continuance of the investment allowance helped towards ship replacement, but was not adequate to allow for expansion which was essential if Britain was to match the increase in tonnage of other nations. This was not a matter about which we could remain complacent and British owners, failing to obtain any relief in taxation were being forced to take action to counteract the commercial advantages enjoyed by owners sailing under flags of convenience by adopting similar measures. Some owners, although continuing to register their ships in Britain, were forming companies in Bermuda and the Bahamas, where profits were not taxed, in order that, Mr. Pelly said, capital could be accumulated with which to finance new building programmes so essential to maintain and expand our mercantile marine. Mr. Pelly, after stating that more shipowners would do the same, went on to underline the importance of our shipping to the nation by pointing out that the merchant navy carried the essential supplies for all three of the fighting Services, and played a vital part in the economic life of the nation by bringing in the raw materials for industry and exporting the finished products.

Involute and Helix Tester for Large Gears

AN involute and helix gear tester, the "Model PGZ," has been introduced by W. Ferd Klingelnberg Sohne, Remscheid, German Federal Republic. It is stated to make possible the testing of profiles on the tooth flanks of gears too large for existing standard equipment. Three models are available, the "PGZ 6/12" for gears of 24in to 47in outside diameter and coarsest pitch 1¼ D.P., the "PGZ 12/27" for 47in to 106in diameter, and 1¼ D.P. coarsest pitch, and the "PGZ 21/60" for 106in to 235in diameter and ¼ D.P. coarsest pitch. Gears of 15 deg. to 25 deg. normal pressure angle, and helix angle up to 45 deg. can be accommodated. Since conventional testers for gears of such large diameters would be extremely heavy and costly, the "Model PGZ" is designed to be mounted on the gears to be checked. This is, of course, a reversal of the normal practice.



Involute and helix tester for gears up to 106in outside diameter. Profile errors are automatically recorded with up to 500 times magnification

The method of operation of the tester makes it necessary to machine a reference register on the gear. While it is important to have this register concentric with the gear axis, the surface finish need not be too expensive, a smooth surface turned with a fine feed being adequate. In certain instances it is possible to use the bore of the gear for this purpose, but if this is not desirable the register should be machined at the same time as the locating face to be used ultimately for locating the gear (generally, the bore).

As may be seen from our illustration, the tester is mounted on a bridge equipped with two rollers fitted with ball bearings running on the face of the gear and two others which run in the reference register mentioned above. The bridge is supported by a framework of tubes forming an approximate isosceles triangle, which is expanded by springs and set according to the gear diameter. This framework also runs on rollers on the gear face and in the register diameter, so that the bridge is held parallel with the gear face and is guided on a circle concentric with the gear axis.

The measuring equipment on the bridge consists of an angular base guiding a roller-supported slide at a tangent to the gear periphery. A roller, having the same diameter as that running in the register, and mounted on a common axis, is held against the slide by spring pressure. Likewise guided tangentially on the outer side of the base is a second slide. A vertical slide, moved by a handwheel operating a rack and pinion, is located on the second tangential slide.

A lever system, accurately set with slip gauges, transmits the motion of the rolling slide to the tangential slide, either directly or at an increased or reduced ratio. Contact with the tooth flanks is made by a vertically adjustable stylus, which can be attached to the vertical or tangential slides.

For checking the involute the stylus is mounted at the end of the tangential slide appropriate to the tooth flank under test, so that it contacts the flank at a tangent to the theoretical base circle. On moving the rolling slide the roller contacting it is turned by friction, and the other roller on the same axis imparts a rotary movement to the entire unit. The circumferential speed on the register corresponds to the tangential speed of the slide and, as the reference circle is not usually identical with the base circle, the lever ratio for transmitting the motion from the rolling to the tangential slide is arranged to reduce or increase the movement of the latter part as necessary. The traverse of the tangential slide corresponds to the rolled arc of the base circle. The stylus thus traces the involute of the gear and transmits any errors to an electric spark recorder, where they are magnified between 50 and 500 times.

For helix testing the stylus is mounted on the vertical slide and applied to the tooth flank. The tangential slide is locked to its base and the link guide set to the required helix angle, the vertical slide being moved parallel with the gear axis. Its traverse controls the motion of the rolling slide and causes the entire unit to revolve around the gear axis, the swivel angle being governed by the vertical slide and the link helix angle. In this way the stylus travels along a spiral relative to the gear, the deviation of the longitudinal flank profile from the theoretical mean being transmitted to the remote recorder in the same way as during the involute test. Sole British agent for the "Model PGZ" is Sykes Machine Tools Company, Ltd., The Hythe, Staines, Middlesex.

Finnish Electric Power Production

Since the war the production of electric power in Finland has undergone a large expansion. The first stage of the hydro-electric programme was completed by the end of 1951, when the installed capacity amounted to 788MW, generating 4500 million kWh in the average year. Thereafter installed capacity and production increased to 1070MW and 5855 million kWh last year (see Table I).

TABLE I—*Growth of Finnish Hydro-Electric Power*

Year	Total Installed capacity (MW)	Average annual output (million kWh)
1951	788	4500
1952	814	4625
1953	857	4830
1954	980	5450
1955	1070	5855

Thermal power comprises an installed capacity of 200MW for back-pressure sets and 400MW for condensing sets. Two additional sets for Vaasa and Parainen power stations will be in operation by the end of 1957, and another station near Helsinki will be begun shortly. In addition to the condensing plant, private firms are constructing for their own factory supplies a number of back-pressure stations totalling some 100MV.

While Finland's total exploitable water power is now estimated to be about 17,000 million kWh in the mean year, the country's power consumption, which last year amounted to 6110 million kWh, is estimated to increase at the rate of 11 per cent per annum until 1960, and at the rate of 8 per cent thereafter. On this basis, a consumption of 14,000 million kWh would be reached by 1965. These figures are based on past experience, the growth over the last five years having been 11 per cent per annum, and 13 per cent over the last three years.

In order to catch up with the rising demand and to safeguard against under-production in dry years, the annual construction, in addition to hydro plant, of 60MW of thermal equipment is envisaged, giving an output of some 800 million kWh.

As regards hydro-electric power stations, two principal plants, as well as a number of smaller stations, are at present under construction. The two plants, Petäjäskoski, on the Kemijoki River, and Utanen, on the Oulujoki River, are due to be completed next year. This will bring the country's installed hydro-electric capacity up to 1280MW, with a generated output of 6860 million kWh in the mean year.

For the financing of these projects of expansion, an annual sum of 20,000,000 Marks will be required. The raising of such amounts presents considerable problems.

In view of the limits which will be reached in the not-too-distant future with the development of traction and power, the government has appointed an Energy Commission to investigate and report on its findings with regard to power. Some organisations and firms are already at work on problems which will arise in the atomic field.

The main hydro-electric stations in Finland are in the north. These include the stations Pälli, Nuojua and Montta, on the River Oulujoki, with a combined installed capacity of 170MW, and a mean annual output of 870 million kWh. The first underground power station in Finland must also be mentioned here, viz., Jumisco, with an installed capacity of 31MW, and a mean annual output of 100 million kWh. This station utilises a head of 96m.

Reservoirs exist at Lakes Saimaa, Oulujärvi and Suolijärvi, the last-mentioned being upstream of the Jumisco plant, which is on a tributary of the Kemijoki River. Distribution is by a 220kV and 110kV grid. One portion of a 380kV supergrid, running from north to south, is under construction; a second such line is still at the project stage.

Zinc-Aluminium-Copper Bearing Alloy

During the second world war, the shortage of copper and tin on the Continent caused a lot of research to be undertaken with a view to finding substitute bearing metals which were not based on those two metals. The war ended before these developments had found a satisfactory solution. Raw materials for the traditional bearing alloys were again available, and it was not until several years later, when copper and tin prices started to climb to the present high levels, that the original research was again taken up.

One of the main difficulties with the binary zinc-aluminium alloys, and also the ternary zinc alloys containing copper up to 3 per cent and aluminium over 10 per cent, was that they were difficult to cast. Later research by the Vereinigte Osterreichische Eisen-und Stahlwerke (VOEST) led to the development of alloys with 30 to 40 per cent aluminium, 5 to 10 per cent copper, and the balance zinc. These "Alzen" alloys eliminated most of the foundry problems and showed a structure similar to the tin bronzes, viz. a finely distributed hard ternary eutectic of copper-aluminium-zinc in a relatively soft matrix of zinc-aluminium. This gave the heterogeneous structure typical of a good bearing alloy.

Most of the Austrian "Alzen 305" production is in the form of sand castings and chill cast bars, for which the alloy had originally been designed, but techniques have also been established for producing "Alzen 305" in the wrought state.

With regard to its properties, "Alzen 305" has a tensile strength of 20 tons per square inch or more, with an ultimate elongation of 2 per cent or over, and a Brinell hardness of 100 to 150. A factor of economic importance is its low specific gravity of 4·8. The coefficient of expansion is higher than that of bronze; on the other hand, the alloy has a thermal conductivity approximately double.

Boundary lubrication characteristics are claimed to be one of the most important aspects of "Alzen 305." Complete seizure will not occur before a bearing temperature of 400 deg. Cent. has been reached, and even in this event the bearing does not weld to the shaft. In consequence there is little or no grooving of the journal.

Corrosion resistance is said to be about midway between the bronzes and zinc base casting alloys, and while insufficient for sea water, has been found satisfactory in the case of pump bearings running with pure water lubrication.

Gravity or pressure die casting may be used in the production of bearings from "Alzen 305," while the techniques applicable to the continuous casting of aluminium alloys can also be employed. Physical properties of continuously cast bar have been very good, ultimate strength reaching 36 tons per square inch, and elongation up to 8 per cent.

"Alzen 305" is made in this country by C. and L. Hill, Ltd., Stringes Lane, Willenhall, Staffs, which has recently been granted exclusive rights to manufacture in the United Kingdom and British Commonwealth, the United States of America, and other countries not covered by the inventors, and a non-exclusive licence for castings and fabricated parts.

Railway Technical Information Exchange

A programme for the intensified exchange of technical information on railway problems was launched last month, following a special meeting of experts from the United States, the U.S.S.R. and the International Union of Railways, representing other European railway administrations. The group of experts met in a five-day session in Geneva from September 3rd to 7th, and after exchanging information on the latest techniques of automation applied to gravity marshalling operations and the use of concrete sleepers, mapped out a two-year programme for international co-operation in the field of railway techniques. This programme was approved by the Sub-Committee on Transport by Rail on September 11th. The railway administrations of Belgium, France, the Federal Republic of Germany, Switzerland, Poland and the Eastern Zone of Germany were represented in the U.I.C. delegation. Representatives of the U.S.S.R. and the U.I.C. presented reports on the automation of gravity marshalling operations. The reports and discussions on them covered layout and shape of tracks, special features of design and equipment for tracks in marshalling yards, track brakes, switch control, communication, work organisation and future automation.

Complete automation is currently being studied by several railway administrations and is included in the future work programme of the group. Automation equipment under study includes teleprinters or pneumatic tubes for transmission of shunting schedules, radio-telephony between foremen and drivers, remote control of locomotives, and various uses for television in marshalling yards. Representatives of the U.S.S.R. and the U.I.C. also presented reports on concrete sleepers; participants at the session evaluated their experiences with the three types of sleepers currently in use—the semi-articulated, combined and single block. Also discussed were fastenings, methods of manufacture of concrete sleepers, electrical insulation, laying on track, and maintenance.

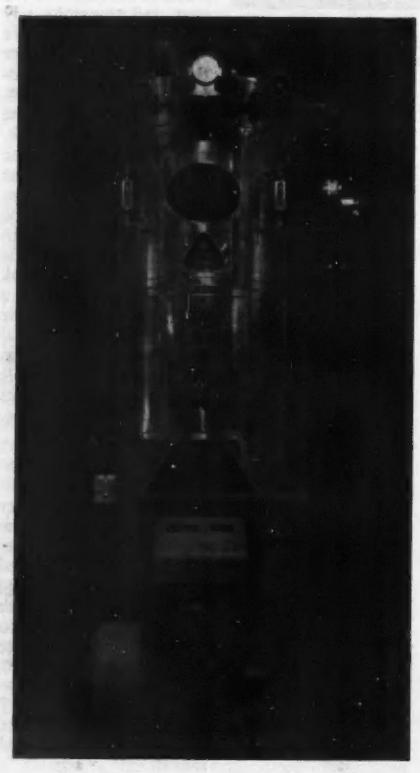
The group found that the relatively short experience so far in the use of concrete sleepers and the variety of conditions of use make it impossible to draw any final conclusions for the moment. For the same reason, they found it impossible to draw up an accurate balance sheet of the economic pros or cons of concrete sleepers and other kinds. Comparisons, it was stated, must take into account not only the cost of the actual sleeper and its transport but also that of its fastenings and maintenance. It was agreed to exchange further technical notes on the following subjects during the first half of 1957: equilateral switching systems and operation and use of the electrically controlled Frölich-Thyssen track brake by the U.I.C.; automatic centralised switch control in a marshalling yard, and telephotographic devices used for transmitting the make-up of trains by the Soviet Union. The group asked the Secretariat to request the Association of American Railroads to submit a note on the automation of gravity marshalling operations on the United States railways.

It was also agreed that the U.I.C. would prepare, during the first half of 1957, a further note on concrete sleepers, with particular reference to calculation of stresses and strains imposed upon concrete sleepers in use, electrical insulation, number and types of sleepers which have been used, deterioration noted, probable life, and manufacturing technology.

All-Fuel Industrial Boiler

The development of all-fuel industrial boilers was first undertaken in France during the occupation, when no liquid fuels and little solid fuel were available. It was then that a section was set up by the National Agency for Coal Rationing to study the problem of making the most of the available inferior kinds of fuel. This committee in turn engaged designers of small and medium boilers to produce a steam boiler which should be of the utmost simplicity, use the minimum quantity of steel, be as economic as possible, and be able to burn any of the available fuels.

One of the upshots of these endeavours was the production, in 1942, of an improved vertical



Vertical all-fuel industrial steam boiler with automatic control

boiler by Société Pradairol, Poujardieu and Cie, 76, Rue Pauly, Bègles (Gironde). Our illustration shows the latest version of this equipment, which is supplied by the factory completely assembled. Designed for small-scale and medium industry, the boiler delivers steam at 10 to 15 atmospheres gauge, and is built in sizes of from 5 to 120 square metres heated area. Complete with feed pump and automatic controls, it is simple to operate, without any refractory linings which are liable to be damaged during transport. The boiler is stated to be suitable for any kind of solid or liquid fuel. Changeover from coal to oil is effected by exchanging the hearth for an oil burner.

Centenary of K.N.S.M.

On October 1, 1856, the Koninklijke Nederlandsche Stoomboot Maatschappij was founded in Amsterdam; after operating for a year as a charter company to gain experience, it ordered its first vessels a year later. Among those ships were three 600-ton steamships with 100 h.p. engines and one 400-ton steamship with a 60 h.p. engine, from Wm. Denny and Brothers, which were completed in May/June, 1857. A 300-ton vessel with a 50 h.p. engine was obtained in July, 1857, from the yard of W. Earle in Hull. These, together with another vessel, formed the nucleus of the K.N.S.M. fleet; all carried sails to assist the engines.

Within twenty years, the company's services had been extended to almost all ports on the European Continent, North Africa, and the Near East. After occasional voyages to America in 1872 and 1873, with smaller vessels, it was decided to order two 3500-ton vessels for the North American route. In 1876, the company participated in the foundation of the Amsterdamsche Rijn-Stoomboot Maatschappij (Amsterdam Rhine Steamship Company). In 1912, K.N.S.M. was amalgamated with the Koninklijke West-Indische Maildienst (Royal West Indies Mail Service).

At the outbreak of war in 1939, the company owned eight passenger ships totalling 46,237 gross tons, and seventy-eight cargo ships, totalling 247,286 tons deadweight; forty-eight ships were lost in the war and 247 members of the staff lost their lives. The seventy cranes of the company's establishment in Amsterdam, and practically all other equipment and buildings were destroyed by the Germans.

After the war the fleet was rebuilt and to-day comprises seventy-seven sea-going vessels, totalling 266,000 tons deadweight, and forty-four Rhine ships, totalling 30,000 tons deadweight. A further fifteen sea-going ships totalling 55,000 tons deadweight are under construction, as well as five Rhine vessels of 500 tons each.

Swiss-U.S. Atomic Agreement

The atomic energy agreement between Switzerland and the United States, which was signed on June 21st, has now been ratified by both chambers of the Swiss Parliament. Concluded for ten years, with the possibility of ending it after five years, the agreement covers the peaceful application of atomic energy, warlike uses being expressly excluded. It deals with the construction and delivery of reactors and provides for the exchange of information, the supply of apparatus and equipment, and the supply of fissile material. The last-mentioned aspect especially will be of great benefit to Switzerland, as it will enable the current researches to be intensified. It will also be possible for Swiss scientists and engineers to visit American installations and research centres. The agreement does not in any way limit the collaboration of Switzerland with other countries in the domain of atomic technology.

Constructional Work in Switzerland

The total value of Swiss constructional projects in the present year is stated to amount to 4400 million francs, an increase of 15 per cent over last year's figure. This sum comprises both public and private work. Of the total, a sum of 445 million is to be spent on road improvements (367 million last year), and 416 million on other civil engineering schemes. For road construction the increase over 1955 is 21 per cent, and for the remainder 45 per cent. Public building projects show an increase of 23 per cent over last year, from 534 million francs to 655 million. In the private building sector, projected work increased by 4 per cent over 1955, to attain a figure of 1500 million francs. Industrial buildings showed a very steep increase from 673 million last year to 933 million this year, a growth of 39 per cent. Hydro-electric schemes amount to 386 million francs, an increase of 9 per cent over last year.

Scattering of Low-Energy Electrons

BY OUR AMERICAN EDITOR

Under the sponsorship of the U.S. Office of Naval Research and the Atomic Energy Commission, the Electron Physics Laboratory of the National Bureau of Standards has been conducting a systematic exploration of the phenomenon of low-energy electron scattering. Using electron beams up to 150keV, the experiments were concentrated on scattering losses below 100eV due to single inelastic collisions. Progress to date includes the development of improved instrument designs, an accumulation of data on various scattering materials and several attempts to develop theories covering the phenomenon involved.

IT has been known since 1926 that when electrons of relatively low energy, less than 150keV, strike a solid surface, some of the scattered electrons lose energy in small amounts that are characteristic of the solid. The same result, representing a line spectrum of energy loss distribution, is obtained when the electrons are scattered by passage through thin layers of solid. Although a number of investigations of the effect have been reported in the last quarter century, considerable uncertainty remains with regard to both the experimental findings and their theoretical interpretation. Much greater attention, in fact, has been directed to the scattering of high-energy electrons, with interest being centred on interactions with nuclei. Seeking a better understanding of low-energy scattering, the National Bureau of Standards, Washington, D.C., has been conducting a systematic exploration of this phenomenon. The programme, which is now in its fifth year, has been directed by the chief of the Bureau's electron physics laboratory, and, more recently, the N.B.S. nuclear physics laboratory has contributed theoretical analyses. The programme is supported by the U.S. Office of Naval Research, the Atomic Energy Commission, and the Bureau itself.

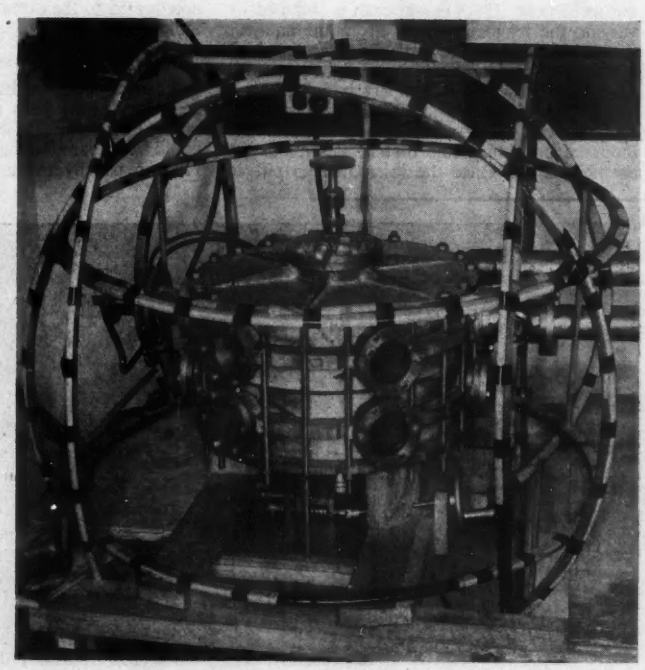
Using electron beams in the range of 0keV to 150keV, the Bureau experiments have concentrated on the scattering losses below 100eV due to single inelastic collisions. It has been found that multiple collisions may be avoided almost completely by using sufficiently thin scattering specimens. So far, there has been progress in several directions; experimetal technique and instrument design have been improved; data have been obtained on a great many scattering materials, and a number of theoretical studies have been made. This systematic study of electron scattering is expected to provide information which is needed in many other fields. First of all, it should throw light on many problems in solid state physics. The well-known applications of solid state physics to semi-conductors and transistors were achieved with only a minimum experimental basis. Thus the results of electron scattering studies should not only strengthen solid state theory, but may well add considerably to its practical potential. Perhaps equally important is the application of scattering data to the study of radiation effects. This is of as much interest in medicine and biophysics as it is in fundamental physics. Most radiation, such as X-rays, does not act directly, but rather by way of the electrons released in matter. Hence, when the action of the individual electron in a single collision is more adequately known, a better picture can be formed of the total effect of the radiation under investigation.

The study also bears directly on problems in electron optics. In the electron microscope, for example, the primary process of image formation is the scattering of electrons in the specimen. If this process introduces differences in the velocities of the electrons, "chromatic" aberration results. This problem served as the impetus for the Bureau's programme of quantitative studies of scattering. Still another phenomenon that may be clarified by electron scattering studies is secondary electron emission, which is essential to the operation of many designs of vacuum valves. Here the new data may add much to the interpretation of observed effects and to the development of better instrumentation.

Instrumentation

Two principal instruments have been used in the experiments at the Bureau, and a third has just been constructed. The first instrument resembles an electron microscope. Based on the method of velocity analysis introduced in 1949 by G. Möllenstedt, it has an energy resolution of one part in 30,000 and is used to study electrons scattered within a small angle (10^{-7} steradian) about the primary beam direction. In the original design, an electron gun sends the primary beam down towards a thin film of specimen. Passing through, the scattered electrons are focused by an electrostatic objective lens into an image on an opaque screen. A slit in the screen allows part of the image to be magnified by a cylindrical lens, the analyser. If the electrons all had one velocity, or the analyser were free of chromatic aberration, a single image of the slit would be formed. However, if the slit is moved away from the optical axis, the chromatic aberration will be greatly increased. The result is a spectrum, with separate images of the slit corresponding to the different velocities of the electrons. The spectrum is recorded on a photographic plate and a microdensitometer is used to determine the energy distribution.

In the Bureau's version of this instrument (Fig. 1), two major improvements were made. It was found, in the first place, that the precision of intensity measurements could be increased by replacing the photographic plate with another kind of detector. This is a fluorescent layer connected by a light pipe to a photo-multiplier. Since only a narrow segment of the spectrum may reach the detector at one time, energy scan is provided by varying the analyser lens potential and recording simultaneously the output of the photo-multiplier. The other change eliminates errors due to chromatic aberration in the objective lens by inverting the positions of objective lens and specimen. With this arrangement, the objective is not used during the actual scattering experiments. It is often convenient, however, to be able to examine an enlarged image of the specimen. To do this, the objective is switched on and a highly reduced image of the electron source is formed just above the specimen. This image, in turn, projects an enlarged shadow image of the specimen on the slit plane. In this and in the other electron-optical instruments designed by the Bureau, an effort is made to use a fixed, well-determined value for the solid angle subtended by the analyser entrance. A survey of previous work in the field showed that this angle was often defined either poorly or not at all. Since studies conducted at the N.B.S. indicate that the angular distributions for elastically and inelastically scattered electrons



Figs. 1 and 2—(Left) N.B.S. instrument for the study of electron energy losses on passage through thin films of solids. (Right) N.B.S. instrument for the study of electrons scattered by thin films of solid at angles up to 150 deg. with the primary electron beam

are quite different, it is clear that investigators using different acceptance angles will obtain different relative intensities and spectral line shapes for the two kinds of electrons.

A second instrument (Fig. 2) was designed by scientists at the Bureau in order to investigate scattering at angles up to 150 deg. from the forward direction of the primary beam. Though having a resolution of only one part in 2000, it is adequate for many purposes. In particular, it made possible the first extensive study of the angular distribution of scattered electrons and gave information about the relation between angle and relative intensities of energy spectrum lines. Measurements with this instrument on a single specimen are conveniently summarised in a cartographic plot (Fig. 3). In this representation angle is the abscissa and energy loss in electron volts in the ordinate. The third co-ordinate, intensity, is shown by contour lines of equal intensity. The use of a quasi-logarithmic sequence of contours permits a compact coverage of an intensity range of 4 to 6000.

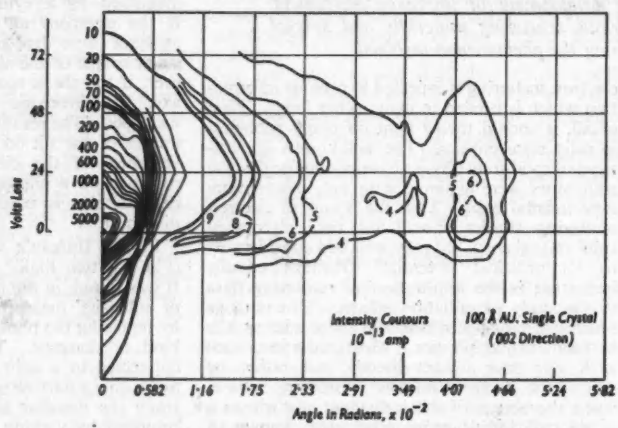


Fig. 3—Cartographic presentation of data showing angular and intensity distribution of electrons scattered by a thin crystal of gold

In the large-angle instrument, scattering occurs inside a cylindrical vacuum chamber 36cm in diameter and 18·5cm high. The specimen is inserted through a port in the top and can be manipulated from the outside. It can also be electrically heated to reduce the rate of specimen contamination to a low level. An electron gun projects radially into the chamber, pointing towards the specimen. Scattered electrons enter a slit in a magnetic analyser, are deflected into a semicircular path by a magnetic field, and leave through another slit in the analyser. The emerging electrons move back towards the axis of the chamber, their directions nearly reversed by the analyser. Only electrons entering the analyser with energy falling within a certain narrow range will reach the exit slit. Those with higher energy, for example, will be deflected along a less curved path, and so will be stopped by the analyser wall ; by increasing the magnetic field intensity these higher-energy electrons may be made to pass through the slit instead of those that did so before. Thus energy scan is obtained by varying the magnetic field. From the analyser the electrons proceed towards the detector, which again is a fluorescent layer, and light generated in the layer by electron impact is guided by a quartz light pipe to a photo-multiplier just below the chamber. The analyser and detector are mounted on a turntable that rotates about the chamber axis. Once the instrument is put in operation, with the analyser set at a given angle with the primary beam, an energy loss spectrum is automatically recorded. The turntable then shifts by 0·00058 radian and the same cycle is repeated every two seconds until the maximum angle is reached. The large hoops surrounding the instrument are Helmholtz coils for neutralising terrestrial and stray magnetic fields.

The two instruments described have yielded and are yielding important data. Nevertheless, greater resolution is required if, for example, the theoretically expected fine structure of scattering loss spectra is to be detected. The relatively undeveloped state of the technique is suggested by the resolution of one part in 100 million attained in light spectroscopy. By contrast, the best electron spectrometers in use at the present time can probably not exceed one part in 70,000. A very promising approach to higher resolution, recent studies indicate, is the use of a decelerating field preceding a magnetic analyser. An instrument of this kind has therefore been constructed and preliminary trials of its operation are under way.

In this instrument (Fig. 4) a Siegbahn magnetic analyser is used, which, by itself, provided a resolution of better than one part in 1000. However, if scattered electrons with an average energy of, say, 50keV, can first be decelerated to an average of 100eV without distorting the energy profile, an overall resolution of one part in 500,000 can be obtained. Also, once the electrons leave the analyser, they may be accelerated to the extent needed to give a strong indication on the detector.

Quantitative Results and Theories

A great many substances, elementary and compound, have been measured with the small angle instrument. Generally, substances that could be prepared in the form of a self-supporting foil were usually investigated as such. Otherwise, supporting substrates were used. For the alkali metals the Bureau's values are the only ones available. They were taken by distilling a thin layer of the metal on to a supporting film (collodion or SiO_2) in the vacuum of the scattering instrument. The vacuum was not very high—of the order of 2×10^{-5}mm of mercury—but high enough to prevent rapid oxidation of the metal. The results here are complicated by the fact that the spectra of the supports are superimposed on those of the substance under study. Also, it is not always possible simply to deduct the substrate lines. Strangely enough, the substrate spectrum seems to be modified when certain metals are applied to it. Whether this may be explained by diffusion of metal into the substrate remains to be shown.

Attention was next given to compounds. A number of simple compounds were measured that show the same spectrum for both element and compound, except that the whole spectrum is shifted towards higher energy values for the compound. The following table summarises some of these results ; it lists energy losses (ΔE corresponding to two or three loss-spectrum lines. A similar shift had been noted in the case of X-ray absorption limits, and several explanations were proposed. K. Das Gupta attempted to relate shifts in the spectra of the components of a compound with the heat of formation. On applying Das Gupta's formula to the case of electron losses, it was found to give the correct order of magnitude and direction of shift, but not much more. The best agreement between calculated and observed values was obtained with the lowest values of ΔE for the sulphides and with the highest values of ΔE for the oxides.

Material	Energy Loss (eV) ΔE_1	ΔE_2	ΔE_3
Si	4·8	16·9	—
SiO_2	5·4	19·4	—
Te	4·6	16·0	—
TeO_2	9·5	17·5	—
Pb	5·1	12·1	21·8
PbS	6·8	14·7	21·9
Sb	4·3	14·9	30·6
Sb_2S_3	6·3	18·0	35·4

In experiments with the large-angle instrument most attention was given to gold. For some of these experiments a film of the substance, 100Å thick, was prepared in the form of a single crystal. Since the energy resolution of this instrument is not as good as that of the small-angle instrument, the characteristic energy loss for gold (24eV) is barely indicated at zero angle by a slight asymmetry in the energy spectrum (Fig. 5). At an angle of 0·0058 radian with the primary beam, however, almost all the intensity appears at 24eV. At still larger angles, for instance, at 0·04 radian, the intensity distribution has two peaks, one for the elastic event and the other for the inelastic one. If intensities are plotted against angle for both zero-loss and 24eV-loss electrons (Fig. 6), it is again seen that the probability for the elastic event is much larger than for the 24eV inelastic one at zero angle. The ratio changes very rapidly, however, and at 0·005 radian the two curves cross over. Then the intensity of the characteristic loss exceeds that of the elastic event until the curves cross again at about 0·042 radian, just before a diffraction maximum. As might be expected, zero-loss electrons predominate at that angle. There is also an increase in the number of inelastically scattered electrons due to double collisions. The cartographic plot (Fig. 3) provides still another representation of these results.

After gold had been studied to some extent, as representative of the heavy elements, attention was turned to the beginning of the periodic system. In the case of beryllium, the most surprising aspect of the scattering distribution is that the inelastic cross section is rather high at the diffraction maxima. Also, for reasons not yet clear, it is not the first and most intense characteristic line of Be at 20eV that appears in the diffraction processes, but a higher energy loss. Aluminium, on the other hand, shows a very well marked centring of the most important diffraction maximum on the zero loss line. The aluminium data are also interesting because of the very steep decline in intensity close to the zero angle, with a thousand-to-one drop within an angle of 0·002 radian.

In addition to obtaining new data on electron scattering, scientists at the N.B.S. have examined

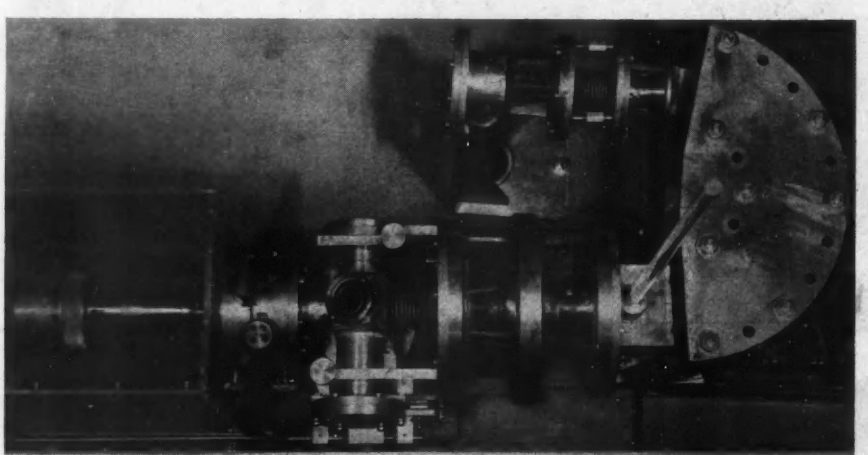


Fig. 4—N.B.S. instrument for the study of the energy distribution of electrons scattered by thin films of solids

the bearing of these results and those obtained elsewhere on the various theories that have been proposed. It is believed that some advances have been made in clarifying the problem and in working out partial solutions. Pending closer comparison with the most recent results of other laboratories, these must be regarded as tentative. Among the theories considered is the so-called plasma theory of Bohm and Pines, which has had considerable success in solid-state physics. In its first version, the conduction electrons of a

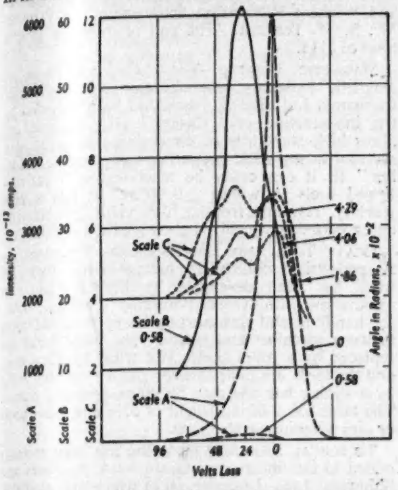


Fig. 5—Energy distributions of electrons scattered at several fixed angles by a single gold film

metal are treated as a Fermi gas which is embedded in a smeared-out medium of fixed positive charge and is excited to collective oscillation by incoming electrons. The theory has the virtue of simplicity, is easy to compare with experiment, and has suggested directions of further research. Nevertheless, it meets with serious difficulties, and these have not yielded to any of the simpler modifications of the theory that seem possible. For example, it predicts only a single energy loss, but more than one is the general rule. As long as these losses are integral multiples of a single value, multiple

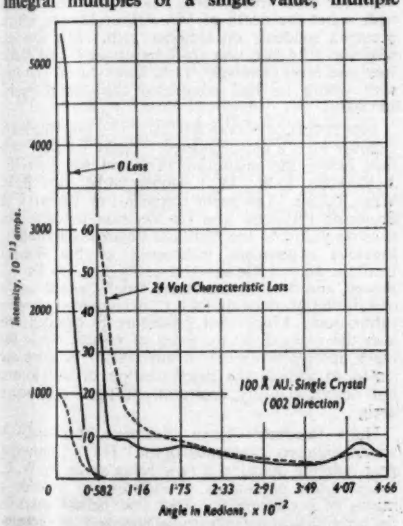


Fig. 6—Angular distribution of zero-loss and characteristic loss intensities for a single gold crystal

collisions could be invoked if the theory could properly explain the minimum loss. Yet in many cases the loss lines are not multiples of a single value.

Another serious drawback is that the collective oscillation description cannot account for lines observed in insulators and metal compounds. Attempts have been made to apply some of the methods of the collective oscillation description to non-conducting media, using an essentially semi-classical treatment of the dielectric. The outlook becomes more promising, however, when a quantum-mechanical analysis of the dielectric constant is made. On the basis of this analysis, the plasma theory can be considered a special case of a broader problem. It is then possible, by employing the quantum-mechanical treatment as a guide, to utilise the semi-classical formula in connection with experiments to obtain needed information on oscillator strengths. Another approach to the problem of electron scattering losses is to compare them with X-ray absorption spectra. The *K*-, *l*-, and other absorption edges are known to shift when an element is replaced by a compound of that element. The work of Das Gupta in this connection has been mentioned above. It is more or less reasonable, therefore, to try to correlate the fine structure of these absorption edges, as well as the fine structures observed at the short wave-length limits, with the characteristic energy losses. A number of attempts in this direction had already been made. At the Bureau, a comparison of this sort was made for the nearly twenty elements and compounds for which the two kinds of data were available, using roughly averaged values for characteristic losses obtained in different laboratories. A high degree of agreement was found.

The search for a physical basis for this result led back to the first attempts to explain electron characteristic losses made by Rudberg, Slater and Haworth twenty years ago. In that interpretation, the observed energy losses are supposed to be caused by excitation of conduction electrons to higher energy levels. These levels are not those of the individual atoms, but are associated with the crystal structure of the solid. This theory is thus another sort of "collective" explanation, but one that takes the specific crystal structure into account. It was used by Slater and Haworth to estimate an energy distribution curve for copper, but only a rather limited agreement with measurements was found. Subsequently, it appeared that experimental difficulties were largely responsible for the latter result. With better techniques, measured and calculated values moved steadily closer. On reconsidering the explanation advanced by Rudberg, Slater and Haworth in the light of the comparison of X-ray and electron data, it was necessary to assume that the characteristic losses, in many cases, at least, represent an inter-band transition from the "Fermi-sea" to the bands above. This is easily acceptable wherever the width of the characteristic line is comparable to that of the Fermi sea. Transitions may then be assumed to take place anywhere within that band. When the observed line is sharper than the width of the Fermi sea, as for aluminium and possibly also beryllium and magnesium, the loss may be ascribed to the excitation of collective oscillations in the electron plasma. The quantum-mechanical treatment mentioned above indicates that for these elements the plasma interaction should be very strong.

An alternative explanation for the case of narrow lines has recently been suggested by T. H. Berlin, of Johns Hopkins University. Since the momentum change in these phenomena is small, it may be assumed that only those transitions are allowed that have small angular momentum changes, e.g. $L=0, 1$. By expressing the distribution function of the Fermi sea in terms of angular momentum about the direction of the incident electrons, it may be possible to find a well-defined stratum giving rise to a sharp transition line. At present, however, much more work, both experimental and theoretical, is needed to decide the issue.

Plans for Further Research

Current plans at the N.B.S. call for the continuation and extension of the electron scattering studies. One important project for which preparations have been made is the study of scattering by metallic vapours. If the energy loss spectra of a metallic vapour is the same as that of the solid metal this would indicate that the collision process involves individual atoms of the scatterer. If the spectra are different, support would be obtained for theories that assume interaction between the electron and the scattering atoms as a collective whole. Modifications of the small-angle instrument have already been made for this purpose. It is hoped shortly to apply the predeceleration instrument to a re-examination of the solid films already measured with other instruments as well as to a study of additional solids. Large-angle scattering measurements will continue on a greater number of substances as guided by theoretical results. Meanwhile, theoretical investigations of energy-loss phenomena will be conducted in parallel with the experimental activities.

Construction of the Priest Rapids Dam in Washington

A CONTRACT has been awarded to the Merritt-Chapman and Scott Corporation, of New York, for the construction of the Priest Rapids dam on the Columbia River in the State of Washington. The Priest Rapids project is the first step in an extensive programme by the Public Utility District of Grant County, Washington, and will create the third largest hydro-electric development in the United States. The contract is believed to be one of the largest construction awards ever made in the Pacific Northwest and the largest ever made to a single contractor. It calls for the construction of an 8412ft long dam of reinforced concrete and earth fill, with an installed generating capacity of 630MW. The Priest Rapids scheme was designed by the Harza Engineering Company, of Chicago, which will supervise construction. The 91,878,625-dollar construction contract represents about 93 per cent of the total cost of construction and equipment; the other 7 per cent will be contracted for at a later date. The entire project is expected to require about four years for completion, with from 2500 to 3000 men employed at the peak.

In addition to Priest Rapids, the Grant County Public Utility District has been licensed by the Federal Power Commission to build a second hydro-electric installation of approximately equivalent size about 18 miles upstream. The construction of this second scheme known as the Wanapum dam, is expected to be started in about two years under a separate contract. Wanapum will have a rated generating capacity of 570MW. Within the United States, the combined 1200MW capacity of Priest Rapids and Wanapum are exceeded only by the Grand Coulee and Hoover dams. The Priest Rapids development is of interest in that it is being financed by the sale of forty-nine-year revenue bonds to be retired through the sale of power. No tax money or government appropriations are to be used for its construction. Twelve public and private utilities in Washington and three other north-western states have signed fifty-year contracts with the Grant County Public Utility District for the purchase of 63·5 per cent of the power generated by the Priest Rapids development. Under their contracts they also agreed to be responsible for the same percentage of the annual cost of the dam, including debt retirement service. Under the allocation plan, the Grant County Public Utility District retains 36·5 per cent of the total power, or about 230MW, for its own use. Other Washington utilities will receive 28·5 per cent, or approximately 180MW, and purchasers in Oregon, Idaho and Montana will take 35 per cent, or 220MW. The purchasers of Priest Rapids power also have an option to buy an equivalent percentage of the power to be generated by the Wanapum development.

Research Reactor for the Battelle Memorial Institute

A LICENCE to operate a research reactor at a site about 15 miles west of Columbus, Ohio, has been issued by the U.S. Atomic Energy Commission to the Battelle Memorial Institute following the completion of a pre-operational inspection. The reactor, which is being constructed for Battelle by the American Machine and Foundry Company, is a modified "pool" facility designed to operate at 1MW, using contained uranium 235 as fuel. Battelle is licensed to possess and use 5·2 kg of contained U-235 in fuel element assemblies and 1·63 grammes in neutron measuring instruments incorporated in the reactor. The reactor will be used in a variety of industrial research activities. The reactor is expected to supply a source of neutrons for conducting exponential experiments on power reactor cores.

Personal and Business

Appointments

SIR HUGH BEAVER has been elected deputy president of the Federation of British Industries.

MR. T. D. JACOBS has been appointed director of instrument production in the Ministry of Supply.

MR. A. KNOWLES has been appointed technical manager, acetylene, of British Oxygen Gases, Ltd.

MR. G. MCONIE has been elected honorary president of the Glasgow University Engineering Society.

MR. D. R. HARRIS has been appointed district manager of the Wembley works of British Oxygen Gases, Ltd.

MR. J. C. BRYCE has been appointed district manager of the Scottish Division of British Oxygen Gases, Ltd.

MR. W. J. A. Sykes has been appointed chief mechanical and electrical engineer, Southern Region, British Railways.

DR. R. LESSING has been elected president of the National Smoke Abatement Society in succession to Sir Ernest Smith.

MR. N. T. STEPHENS has been appointed a partner in the company of Rodger Setterington and Partners, consulting engineers.

MR. C. A. FRENCH has been appointed a deputy chief accountant at the headquarters of the Central Electricity Authority.

THE BRITISH TRANSPORT COMMISSION announces the appointment of Mr. D. M. Dear as director of costings at its headquarters.

MR. S. W. EVANS has been appointed works manager of the East Moors Works, Cardiff, of Guest Keen Iron and Steel Company, Ltd.

MR. D. E. BAKER, A.M.I.Mech.E., has been appointed managing director of E. T. Oakes, Ltd., the British subsidiary of the E. T. Oakes Corporation, New York.

MR. A. J. WOOLCOTT has been appointed chairman and managing director of Wellworthy, Ltd., in succession to Mr. J. W. Howlett. Mr. Howlett remains a director of the company.

WING COMMANDER A. E. DALE has been appointed executive to carry out liaison duties in connection with aircraft fuel pump products of the Pulsometer Engineering Company, Ltd.

SIR NUTCOMBE HUME has been appointed chairman of Edmundsons Electric Company, Ltd., 30, Gillingham Street, London, S.W.1, in succession to the late Brigadier-General Wade H. Hayes.

MR. G. F. ALEXANDER, a director of George H. Alexander Machinery, Ltd., Birmingham, has been elected president of the South African branch of the Institute of British Foundrymen.

GEORGE COHEN, SONS AND CO., Ltd., announces that Mr. J. A. J. Blanckensee, Mr. D. W. Cooper, Mr. A. S. Gill, Mr. C. E. G. Nye, Mr. J. H. Pawley and Miss E. P. Wood have been appointed directors.

THE ROYAL SOCIETY states that the War Office has agreed to the appointment of Colonel Robin Smart, R.A.M.C., as leader of the main party of the Royal Society International Geophysical Year Antarctic Expedition.

Business Announcements

THOMAS SMITH AND SONS (RODLEY), Ltd., announces that Mr. C. Walls has retired from the board of directors.

SIMMS MOTOR UNITS, Ltd., announces that it has taken over the Industrial Fan and Heater Company, Ltd., of Birmingham.

THE BRUSH GROUP (SOUTHERN AFRICA), Ltd., has moved into new premises at 44–46, Third Street, Booysens Reserve, Johannesburg.

COSSOR COMMUNICATIONS COMPANY, Ltd., has been formed as a subsidiary of A. C. Cossor, Ltd., to extend the telecommunications interests of the Cossor Group.

ARTHUR WILLIAMS AND CO., 164, Chester Road, Manchester, 15, is now the Lancashire area sales representative of Martindale Electric Company, Ltd., Westmorland Road, London, N.W.9.

YARROW AND CO. Ltd., announces that Mr. W. E. Young is to retire, and is resigning from the board of directors of the parent company and also from the board of Yarrow (Africa) (Pty.), Ltd., on December 31st.

MR. VAUGHAN PENDRED, managing director of the Head Wrightson Export Company, Ltd., is visiting Calcutta, in connection with his company's contract for three blast-furnaces to be constructed at Durgapur, West Bengal.

THE COUNCIL OF INDUSTRIAL DESIGN announces that Sir Gordon Russell attended the opening of the Design Centre in Ottawa on October 17. In a fifteen-day tour he will lecture on industrial design on behalf of the National Industrial Design Council of Canada.

TUBE INVESTMENTS, Ltd., states that it has acquired from the Iron and Steel Holding and Realisation Agency the whole of the issued capital of the Renishaw Iron Company, Ltd., in North Derbyshire, and a half share in the Byfield Ironstone Company, Ltd., between Banbury and Daventry.

THE CATERPILLAR TRACTOR COMPANY, of Peoria, Illinois, states that as from January 1, 1957, overseas operations will be regrouped to form a combined foreign trade group. This group will include Caterpillar Tractor Company, Ltd., (England), Caterpillar Brazil, S.A., and Caterpillar of Australia Pty., Ltd.

SALOPIAN ENGINEERS, Ltd., states that it has been reconstituted from a manufacturing and sales company to a marketing company only. Mr. A. G. Burgess has been appointed managing director of the marketing company, retaining his position as divisional manager of the contracts division.

HEPBURN CONVEYOR COMPANY, Ltd., states that it has obtained sole manufacturing rights in Great Britain of the shot blasting and dust control equipment of the Pangborn Corporation of Hagerstown, Maryland, U.S.A., and the selling rights for Great Britain, the sterling area, and non-exclusive rights for other countries, including Germany and India.

Contracts

COSTAIN-JOHN BROWN, Ltd., has received from Chemstrand, Ltd., the contract (valued at £3,500,000) for the design and construction of an "Acrilan" fibre plant at Coleraine, Northern Ireland.

METROPOLITAN-VICKERS ELECTRICAL COMPANY, LTD., has received an order for electrical generating plant worth £224,000 for Canada's first nuclear power project. The power station, which will be operated as part of the 230kV system of the Ontario Hydro-Electric Power Commission, will be situated at Des Joachims on the Ottawa River, nearly 150 miles north-west of Ottawa. It will consist of a nuclear reactor, to be built by the Canadian General Electric Company to the design of Atomic Energy for Canada, Ltd., and boiler plant and generating plant with an output of 20MW. The Metropolitan-Vickers contract covers a 20MW, 3600 r.p.m. turbine generator set with condensing and feed water heating plant, to be made at Trafford Park and Germiston. It is a single-cylinder turbine and is very similar to a 30MW machine supplied to the Estevan power station of the Saskatchewan Power Corporation. It operates with three-stage feed water heating to 300 deg. Fah. and condenser vacuum of 28·5in Hg. and takes dry saturated steam at 400 p.s.i.g. by group admission from the steam chest, which is integral with the top half of the turbine casing at the high-pressure end. At an intermediate point in the expansion, all the steam is taken out and passed through a separator to remove most of the water. The steam is returned to the turbine, where it is expanded normally through the remaining stages, and thence to the condenser. Special stage drainage will be provided to limit exhaust wetness. The turbine rotor will be carried in two journal bearings, that at the high-pressure end being combined with a Michell thrust bearing. All moving blading will be of stainless steel.

Miscellanea

CORRECTION.—In our review of the treatise *Geoelektrische Bestimmung von Schichtgrenzen eines tertiären Plateaus mit Quartärbedeckung* (THE ENGINEER, August 31, 1956, page 305), we erroneously gave the author's name as Max Weber, instead of Nasser Tarass, as should have been stated.

MR. ROBERT MACGREGOR.—It is with regret that we record the death of Mr. Robert MacGregor, which occurred at his home in Whitley Bay. Mr. MacGregor, who was a director of MacGregor and Co. (Naval Architects), Ltd., began his career with Palmers Shipbuilding and Iron Company, Ltd., and after experience at home and abroad joined his brother, Mr. Joseph MacGregor, in design and production of steel hatch covers for ships.

NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—The report of the Council of the North East Coast Institution of Engineers and Shipbuilders for 1955–56 states that thirteen papers were read and that the M. C. James medal was awarded to Dr. J. F. Allan and Mr. R. S. Cutland for their paper "The Effect of Roughness on Ship Resistance." A paper entitled "The Optimum Diameter of Marine Propellers" gained the Shipbuilding Gold Medal for Professor L. C. Burrill, who was also awarded the Amos Ayre prize. The report records the award of the Thomas Fenwick Reed Medal to Mr. N. A. Roberts, B.Sc., and the following scholarship awards: the Institution scholarship to Mr. M. McDonald, the George Mitchell Harroway Scholarship to Mr. J. L. Balmer, the Doxford Scholarship and Prize to Mr. R. G. Munro, and the Swan, Hunter and Wigham Richardson Scholarship and Prize to Mr. S. M. Tennant. The roll of members gave a total of 2113.

MAGNETIC FERRITE.—The "Caslon" range of magnetic materials, manufactured by the Plessey Company, Ltd., Ilford, Essex, has been extended by the introduction of "Caslon" III. Intended to allow high standards of dimensional accuracy at a sacrifice in magnetic properties compared to "Caslon" II, it can easily be machined with carbide-tipped tools to within ±0·005in. It has a high stability, resulting from a high value of coercivity and a permeability only slightly greater than unity.

HEAVY TOOL AND DIE HANDLING EQUIPMENT.—A pedestrian controlled, battery-driven fork lift truck has been developed by Matling, Ltd., in association with Talbot-Ponsonby and Co., Ltd., for handling and transporting heavy dies and tools between machines and stores. The usual forks are replaced by a roller table, 34in wide by 32in long, and the tools are pulled on or pushed off this table by a sliding bar operated by crank-operated chains. The table has a lifting height of 53in and takes tools or dies weighing up to 3 tons.

TECHNICAL FILMS.—A new film has been recently added to the library maintained by A. A. Jones and Shipman, Ltd., Leicester, all of which are available for loan to technical and trade organisations, societies and colleges. This film is entitled "Cutter and Tool Grinding, Model 310," and it describes the controls, functions and operation of the firm's Model 310 machine. Amongst the other films now available from this company are the following: "To be Precise," "Surface Grinding," "Precision Grinding Model 1300/5," "Generation of Metallic Bearing Surfaces," and "Progress in Precision."

OBITUARY.—We have learned with regret of the death, on October 5th, of Mr. A. D. Markland, who spent forty-three years in the service of the British Thomson-Houston Co., Ltd. Mr. Markland, who was eighty, joined the turbine department of B.T.H. in 1903. When he retired in 1946, he had been the assistant manager of the turbine contracts department for more than twenty years. We also record with regret the death of Mr. Arthur Davies, which occurred suddenly on October 11th. Mr. Davies, who was fifty-five, was chief buyer for Guest Keen Iron and Steel Company, Ltd., East Moors, Cardiff, with whom he had completed thirty-eight years' service.

INSTITUTION OF NAVAL ARCHITECTS.—On Thursday, October 11th, a paper entitled "Yacht Testing" was read before the Institution of Naval Architects by J. F. Allan, D.Sc., D. J. Doust, M.Sc., and B. E. Ware, B.Eng. The paper comments on the work of Professor Davidson and the decision to carry out tests on yachts at the National Physical Laboratory. Previous experiment techniques at the Stevens Institute and at Genoa University and by Dr. G. Kempf and Mr. Marshall are briefly noted and a description given of the N.P.L. dynamometer and its calibration. Model test procedure is detailed and also the method of analysing of results, while the items upon which research has still to be done are stated to include the determination of sail forces, hull design, stability, centre of effort and appendage design.

HIGH PRECISION GEAR HOBBING MACHINE.—A special high precision model of the "HV14" universal gear hobbing machine is now being made by W. E. Sykes, Ltd., of Staines, Middlesex, to provide a means of producing fine spur and helical gears to the very close tolerances now specified by Government departments and other bodies. This machine, like the standard model, produces spur gears, right and left-hand helical gears, and worm wheels up to 14in diameter and 6 D.P. It is stated by the maker that on the machine large gears can be cut which show a maximum total error of only 0·0004in to 0·0005in when roll-tested with a master gear. A tolerance of this order can be obtained with spur gears of 528 teeth and 32 D.P., and gears with both backlash and cumulative pitch errors of less than 0·0005in can be cut. To obtain the high degree of precision attainable on this machine all of its component parts are made to very close tolerances and tested on assembly to ensure that such things as cumulative pitch errors in gears are avoided, spindle centre distances are exact and rotational relationships of all operative shafts are correct to very small angular tolerances.

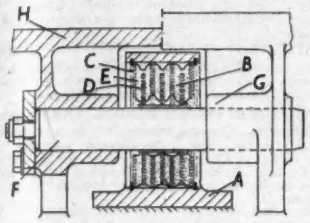
British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. each.

RAILWAY ENGINEERING

757,622. December 21, 1953.—The Resilient Mounting of Engines in Vehicles, Mak Maschinenbau Kiel Aktiengesellschaft, Kiel-Friedrichsort, Germany. (*Inventors: Otto Butter and Alfred Renner.*)

The invention relates to the resilient mounting of internal combustion engines in railway vehicles, its object being to provide a construction which is particularly simple to assemble, and which provides the same degree of stability in both the vertical and horizontal directions. The engine is mounted on the chassis frame by means of three mounting



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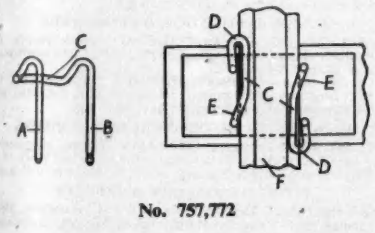
assemblies, each of which includes a bracket *A* on the frame. The resilient elements *B* are fitted in the bracket and consist of a pair of metal plates *C* and *D*, with a rubber member *E* bonded between them. A coupling pin *F* is engaged concentrically through each plate *D*, whilst the plates *C* have a central aperture which is considerably larger than the pin so that it can move radially within limits. The plates *C* are held at their outer edge in the brackets *A*. Webs *G* are arranged in pairs on the crankcase *H* of the engine, and between the webs of each pair the bracket is so arranged that the pin *F* rests in trunnion portions of the webs, as shown in the drawing. Several such mounting means, including the bracket and pair of webs, may be arranged at each side of the engine, to provide resilient support in vertical and horizontal directions.—*September* 19, 1956.

757,772. August 27, 1954.—Resilient Rail Spikes, Karl Grönn, of Wergelandsveien 5, Oslo, Norway.

The invention relates to resilient rail spikes for fastening a rail to a support. The object is to provide a rail spike which, when in use, automatically blocks the rails against displacement in longitudinal direction. As will be seen from the drawing, the rail spike comprises two parallel legs *A* and *B* interconnected by an integral transverse member *C*.



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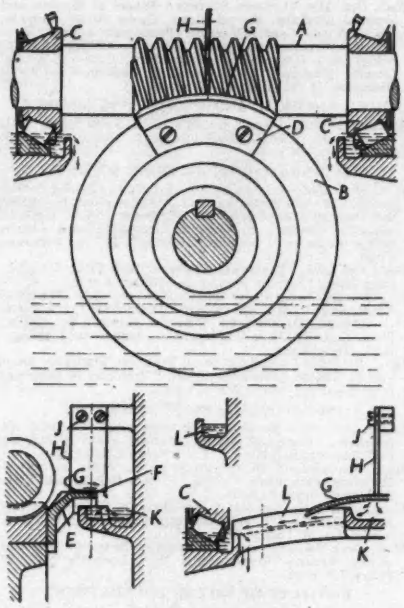
The transition from each of the legs to the transverse member consists of an integral portion *D* or *E*, respectively, each extending in a sidewards direction and acting in a resilient manner when the rail spike is in use. Preferably each of these portions is of semi-circular shape, but within the scope of the invention other shapes differing more or less from such semi-circular shape may be used, provided such shape affords sufficient resiliency. Moreover, the portions *D* and *E* are also bent somewhat backwards, so that the transverse member *C* extends in a plane behind a plane extending through both legs *A* and *B*. The legs of the rail spike may simply have a somewhat pointed end, as shown on the leg *A*, or may be provided with one or more circumferential depressions, as shown on the leg *B*. For fastening a rail, two similar rail spikes are used, as shown in the drawing, so that they fasten a rail *F* to a tie plate and a sleeper and they are placed in opposite directions at the two sides of the rail.—*September* 26, 1956.

POWER TRANSMISSION

757,480. December 20, 1954.—Lubricating Worm Gears, Allmanna Svenska Elektriska Aktiebolaget, Vasteras, Sweden. (*Inventor: Oscar Johansson.*)

The invention relates to an improvement in means for lubricating worm gears. In the Specification No. 726,529 there is described means for the lubrication of the tooth engagement point in a worm gear having the worm arranged above the worm wheel. The object of the present invention is to provide a worm gear lubricating means by which the bearings of a worm gear as well as the engagement



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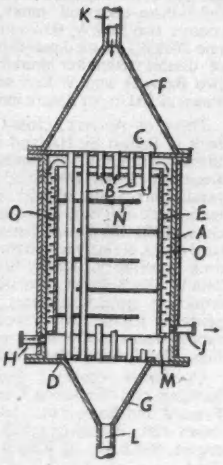
point of the teeth can be lubricated. In the drawing, *A* is the worm and *B* the worm wheel. The bearings of the worm are *C*, and *D* is an oil carrier fixed to one or to both sides of the worm wheel for the oil supply to the engagement point of the teeth as well as to the bearings. The oil carried along by the part *E* of the carrier *D* is supplied to the engagement point of the teeth and the oil carried along by the part *F* of the carrier is supplied to the bearings. The surface of the part *E* may be smooth or grooved or provided with projections or folds, dependent on the consistency of the oil used. The surface *G* of the part *F* may be shaped as a part of a cylindrical surface or as a part of the surface of a cone, arranged concentric with the axis of the wheel. A stripper *H* is fixed in the gear casing and is adjustable with respect to the surface *G* through the provision of slotted holes in the stripper which are engaged by the screws *J*. This stripper directs oil from the surface *G* to a trough *K*. From the trough the oil is led through channels *L* to the bearings *C*. In the same way oil can be transported to other bearings not shown in the drawing.—*September* 19, 1956.

HEAT EXCHANGERS

758,030. February 3, 1954.—Tubular Heat Exchangers, Esso Research and Engineering Company, formerly Standard Oil Development Company, Elizabeth, New Jersey, U.S.A.

The invention concerns the alleviation of mechanical stresses of structures due to differential thermal expansion of constituent members, and is concerned with tubular heat exchangers in which any differential between the tube and shell metal temperatures is essentially eliminated by installation of a concentric baffle which separates the shell from the extreme-temperature fluid entering the exchanger. Referring to the drawing, the heat exchanger may comprise an outer cylindrical shell *A*, in which is placed a tube bundle composed of tubes *B* held between tube sheets *C* and *D*. In general it is desirable to have at least one of these sheets, such as sheet *D*, sufficiently small in diameter to clear not only the shell *A* but also the cylindrical baffle *E* to permit sliding the entire tube bundle from the shell for cleaning or repairs, when necessary. The exchanger also comprises headers *F* and *G*, which form the terminal walls of the shell. The unit also includes ports *H* and *J* for introducing one fluid into and withdrawing it from exchanger shell, as well as ports *K* and *L* for feeding the other fluid into and withdrawing it from the headers which communicate with tubes. Finally, the exchanger also contains a concentric baffle or inner shell *E* which embodies the real essence of the invention, since it serves to keep the cool shell fluid from undue direct contact with the lateral shell wall *A*. Thus the baffle may comprise a cylindrical sleeve portion *E* fastened to shell wall *A* by the solid horizontal or base portion *M*. In order to improve uniform distribution of fluids in the heat exchanger it may also be desirable to have laterally staggered horizontal flat baffles *N* spaced about 6in to 8in above each other. It may be desirable to improve distribution of fluid over the shell wall by installing suitable baffling in the annulus created by cylindrical baffle *E*. For this purpose perforated transverse discs or grids *O* or spiral baffles or the like may be used, in which case such baffling may also be used to give mechanical support and rigidity to the loose end of cylindrical baffle *E*. In a typical commercial embodiment the lateral shell wall *A* may be about 25ft high and have an inside diameter of 45in. Baffle *E* may be spaced about 0·5in to 3in from the shell wall, depending somewhat on the diameter of the vessel and the quantity of gas being handled on the shell side. Generally it is desirable to make the cross-section of the annulus approximately equal to the capacity of the pipelines leading to nozzles *H* and *J*. The height of the baffle may be about 24ft, though other heights within the approximate range of from about 50 to 98 per cent of the height of the lateral shell wall may be preferred, depending on specific conditions.—*September* 26, 1956.

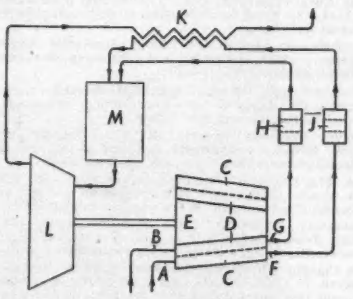


No. 758,030

GAS TURBINES

757,940. March 19, 1954.—Gas Turbine Power Plants, The English Electric Company, Ltd., Queens House, 28, Kingsway, London, W.C.2. (*Inventor: Robert James Welsh.*)

The invention relates to internal combustion gas turbines. It is often desired to burn in a gas turbine plant a gas fuel that is available at a pressure approximating atmospheric or at least at too low a pressure for it to flow into the combustion chamber without assistance. It is an object of the present invention to dispense with a separate gas compressor and with a catalytic lining (see Specification No. 741,506) of the combustion chamber, by compressing both the gas fuel and the air in a single compressor but to delay the intimate mixing of the gas fuel and the air until both have been introduced into the combustion chamber. Referring to the drawing, air is supplied through the duct *A* and gas fuel through the duct *B* into two coaxial zones *C*, *D* of a multi-stage axial flow compressor denoted *E* as a whole, and after compression the air is discharged at *F* and the gas fuel at *G* respectively through flame traps *H*, *J*, which prevent any blow-back into the compressor in case unintentionally the air in zone *C* or gas fuel in zone *D* should be mixed with each other to such an extent as to become explosive. Gas fuel is passed directly and air is passed through the cold pass of a heat exchanger *K* into a combustion chamber *L*, from where the combustion products are passed through the gas turbine *M* and hot pass of the heat exchanger *K* in succession. The blading both of the rotor and of the stator may be of the free vortex type or alternatively the radial length of the rotor and/or stator blades may be divided by means of platforms in order to aid the separate flow of the two gaseous media through the compressor. In case the gas fuel is of higher density than the air the position of the coaxial air and gas annuli would have to be reversed.—*September* 26, 1956.



No. 757,940

Launches and Trial Trips

HARVELLA, oil tanker ; built at Belfast by Harland and Wolff, Ltd., for Shell Tankers, Ltd. ; length between perpendiculars 530ft, breadth moulded 69ft 3in, depth moulded 39ft, deadweight 18,200 tons ; thirty-three cargo oil tanks, one main cargo pump room ; two 550kW, 60 c/s turbine-driven alternators, one 200kW, 60 c/s diesel-driven alternator ; one set of double reduction geared turbines, 7500 s.h.p. ; two Babcock and Wilcox water-tube boilers supply steam at 500 lb per square inch and 800 deg. Fah.

DUKE OF ARGYLL, cross-Channel passenger ship; built at Belfast by Harland and Wolff, Ltd., for the British Transport Commission (London Midland Region) ; length overall 375ft, length between perpendiculars 354ft, breadth moulded 55ft, depth to main deck 19ft 6in, gross tonnage 4800 ; 600 first-class, 1200 third-class passengers ; two complete steel decks, eleven water-tight compartments ; electric deck machinery, Denny-Brown stabiliser ; three 240kW diesel-driven generators ; two sets of double reduction geared turbines, 10,500 s.h.p. at 225 propeller r.p.m., two Babcock and Wilcox boilers supply steam at 350 lb per square inch and 700 deg. Fah.—Trial, September 22nd.

CENTURITY, coaster ; built by the Goole Shipbuilding and Repairing Company, Ltd., for F. T. Everard and Sons, Ltd.; length 190ft, breadth 30ft, depth 12ft, deadweight 885 tons ; Newbury diesel engine, 600 b.h.p. at 300 r.p.m. Launch, September 22nd.

T.I.C. No. 26, hopper barge ; built by William Simons and Co., Ltd., for the Tyne Improvement Commission ; length 144ft, breadth 31ft, depth 13ft 9in, designed to hold 600 tons of fine silt ; Widdop six-cylinder pump, scavenged, two-cycle diesel engine. Launch, September 25th.

CLOVELLA, trawler ; built by John Lewis and Sons, Ltd., for the Clova Fishing Company, Ltd.; length overall 122ft, breadth 24ft, depth moulded 11ft 6in, gross tonnage 220 ; fishroom 5500 cubic feet, 100 b.h.p. electric trawl winch to take 800 fathoms of 2¼in warp ; two 20kW diesel-driven generators, one 82½kW trawl winch generator ; British Polar M.44 M diesel engine, 640 b.h.p. at 250 r.p.m. Launch, October 4th.

Catalogues and Brochures

SIGMUND PUMPS, Ltd., Team Valley, Gateshead.—Illustrated eaflet giving details of an integral pumping set.

PETBOW, Ltd., Sandwich, Kent.—Leaflet giving details of engine-driven welding plants; the technical details of these plants are illustrated.

THE COPAC COMPANY, Ltd., 2, Ullswater Road, London, S.W.3.—Leaflet giving details of industrial stethoscopes for testing machinery and plant.

AKTIEBOLAGET LUNDEN AND LINDHE, Stockholm, Sweden.—Catalogue Nr.400, describing and illustrating the range of products manufactured by this firm.

LIONWELD, Ltd., Marsh Road, Middlesbrough.—Catalogue illustrating the ranges of open steel flooring, stair-treads and hand-railing manufactured by this firm.

CRAVEN BROTHERS (MANCHESTER), Ltd., Vauxhall Works, Reddish, Stockport.—Illustrated catalogue giving full details and specifications of their latest range of wheel lathes.

THE ELECTRICAL APPARATUS COMPANY, Ltd., St. Albans, Herts.—Leaflet giving details of motor control gear and instruments, including the amount in stock and their dispatch service.

BROADWAY EQUIPMENT, Ltd., Paraway House, 194–196, Finchley Road, London, N.W.3.—Leaflet giving brief particulars of a new trolley for use in lifting cranes, uneven shapes, work pans.

THE CLEVELAND TRENCHER COMPANY, 20,100, St. Clair Avenue, Cleveland, 17, Ohio, U.S.A.—Leaflet No. L-101, describing and illustrating trenchers and backfillers, for every kind of trenching job.

LINCOLN ELECTRIC COMPANY, Ltd., Welwyn Garden City, Herts.—Illustrated catalogue entitled "Lincoln Weldirectory," dealing with the complete range of products produced by this company.

SCIAKY ELECTRIC WELDING MACHINES, Ltd., Farnham Road, Slough, Bucks.—A brochure entitled "A Few Sciaky Standard Machines." It describes and illustrates their regular standard machines.

THE MAGNETIC EQUIPMENT COMPANY, Ltd., Lake Works, Portchester, Hants.—Leaflets containing illustrations and details of the standard ranges of "Magco" bin vibrators and vibratory control gear.

KESTNER EVAPORATOR AND ENGINEERING COMPANY, Ltd., Grosvenor Gardens, Westminster, London, S.W.1.—Illustrated catalogue giving specifications of a selection of laboratory and pilot equipment.

NEWALL GROUP SALES, Ltd., Old Fletton, Peterborough.—Brochures covering new and modified products made by this company, including boring machines, precision cylindrical grinders and jig borers.

BARDSLEY-COLCHESTER, Ltd., 196, Bercholt Road, Colchester.—Leaflets giving details of some of the products manufactured by the company, including tubular steel trucks and wheelbarrows, aluminium steps and ladders.

CONSOLIDATED PNEUMATIC TOOL COMPANY, Ltd., 232, Dawes Road, London, S.W.6.—Catalogue of British-made pneumatic tools and compressors, ranging from pneumatic riveting tools to oil-flooded rotary portable air compressors.

THE CROWTHORN ENGINEERING COMPANY, Ltd., Reddish, Stockport.—Brochure dealing with 12/12½in heavy duty centre lathe designed to achieve a high rate of production, making maximum use of either high-speed or tungsten carbide tools.

THE HOFFMANN MANUFACTURING COMPANY, Ltd., Chelmsford, Essex.—Publication No. B22/QQUU, entitled "Bearing Symbols with Hoffmann Equivalents," compiled to enable designers and those engaged in servicing work to easily identify a similar make of bearing.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

Sat., Oct. 20th.—OXFORD, READING AND DISTRICTS BRANCH : Collier Lecture Room, Regents Park College, Pusey Street, Oxford, "Nuclear Reactors and Instrumentation," D. D. Bowen, 6.30 p.m.

BRITISH INSTITUTION OF RADIO ENGINEERS

Wed., Oct. 31st.—LONDON SECTION : School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1, Annual General Meeting. Presidential Address, G. A. Marriott, 6 p.m.——S. WALES SECTION : College of Technology and Commerce, Cathays Park, Cardiff. Annual General Meeting, "Applications of Transistors to Radio Reception," L. E. Jansson, 6.30 p.m.

HULL CHEMICAL AND ENGINEERING SOCIETY

Tues., Oct. 23rd.—Church Institute, Hull, Film Show, "Air Compressors, their Manufacture and Use," C. A. F. Mackintosh, 7.30 p.m.

ILLUMINATING ENGINEERING SOCIETY

Mon., Oct. 22nd.—LEEDS CENTRE : E.L.M.A. Lighting Service Bureau, 24, Aire Street, Leeds, 1, "Decorative Lighting and the Designer's Approach," D. W. Durrant, 6.15 p.m.——LEICESTER CENTRE : E. Midlands Electricity Board, Charles Street, Leicester, "Aviation Lighting," H. M. Ferguson, 6 p.m.

Wed., Oct. 24th.—TRANSVAAL CENTRE : New Club, Johannesburg, Annual General Meeting and Dinner, 6 p.m.

Fri., Oct. 26th.—BATH AND BRISTOL CENTRE : S.W. Electricity Board, Bath, "Light and the Eye," Drummond Curry, 7 p.m.——BIRMINGHAM CENTRE : "Regent House," St. Phillip's Place, Colmore Row, Birmingham, "Aerodrome Lighting," J. W. Morse, 6 p.m.

Mon., Oct. 29th.—LEEDS CENTRE : Yorkshire Electricity Board Lecture Theatre, Ferensway, Hull, "Problems of Shop and Store Lighting," K. C. White, 7 p.m.

INCORPORATED PLANT ENGINEERS

To-day, Oct. 19th.—BIRMINGHAM BRANCH : Imperial Hotel, Birmingham, "Electrical Safety Concerning Building Sites and Civil Engineering Projects," G. L. Leighton, 7.30 p.m.

Tues., Oct. 23rd.—S. WALES BRANCH : S. Wales Institute of Engineers, Park Place, Cardiff, "Steam Raising and Boiler Problems," films, 7.15 p.m.

Thurs., Oct. 25th.—SHEFFIELD AND DISTRICT BRANCH : Grand Hotel, Sheffield, "A Practical Approach to Industrial Electronics," A. M. Lock, 7.30 p.m.

Mon., Oct. 29th.—W. AND E. YORKSHIRE BRANCH : The University, Leeds, "Commonsense Fuel Economy," C. W. Peters, 7.30 p.m.

INSTITUTE OF BRITISH FOUNDRYMEN

Sat., Oct. 20th.—NORTHAMPTON SECTION : Works Visit to Foundry Equipment, Ltd., Leighton Buzzard, 10.15 p.m.

Wed., Oct. 24th.—BIRMINGHAM BRANCH : James Watt Memorial Institute, Great Charles Street, Birmingham, 3, "Experience in the Use of a Coreless Normal Frequency Melting Furnace," T. R. Twigger, 7.15 p.m.

Sat., Oct. 27th.—BRISTOL AND W. OF ENGLAND BRANCH : Grand Hotel, Broad Street, Bristol, "Some Developments in Foundry Sands Practice," A. Tipper, 3 p.m.

INSTITUTE OF MARINE ENGINEERS

Mon., Oct. 22nd.—WEST OF ENGLAND SECTION : Grand Hotel, Bristol, "The Gas Turbine," A. W. Pope, 7.30 p.m.——N.E. COAST SECTION : Marine and Technical College, South Shields, "Boiler Water Treatment," J. F. Colville, 4 p.m.

Tues., Oct. 23rd.—JOINT MEETING WITH THE INSTITUTION OF NAVAL ARCHITECTS : 85, Minories, London, E.C.3, Symposium, "Fires in Ships," 10.30 a.m.

Wed., Oct. 24th.—SCOTTISH SECTION, JUNIOR LECTURE : Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, C.2, "The Junior Engineer's First Trip to Sea," H. C. Gibson, 7.30 p.m.

Thurs., Oct. 25th.—Jury's Hotel, Dame Street, Dublin, "Exhaust Steam Uses," P. A. Scanlan, 7.30 p.m.——SCOTTISH SECTION : JUNIOR LECTURE : Dundee Institute of Engineers, Engineering Department, University College, Dundee, "The Junior Engineer's First Trip to Sea," H. C. Gibson, 7.30 p.m.——S. WALES SECTION, JUNIOR LECTURE : Swansea Technical College, Mount Pleasant, Swansea, "Engine Room Equipment," D. C. Hagen, 2 p.m.

INSTITUTE OF METALS

Mon., Oct. 22nd.—SHEFFIELD LOCAL SECTION : Engineering Lecture Theatre, The University, St. George's Square, Sheffield 1, "Bessemer and His Process," J. Mitchell, 7.30 p.m.

Thurs., Oct. 25th.—BIRMINGHAM LOCAL SECTION : Exchange and Engineering Centre, Stephenson Place, Birmingham, "Dry Corrosion," E. C. Williams, 6.30 p.m.

INSTITUTE OF NAVIGATION

Wed., Oct. 24th.—Royal Geographical Society, 1, Kensington Gore, London, S.W.7, "Off the Beaten Track," 2.15 p.m.

INSTITUTE OF PHYSICS

To-day, Oct. 19th.—NON-DESTRUCTIVE TESTING GROUP : 47, Belgrave Square, London, S.W.1, "Fluoroscopy, with an Enlarged Image," R. Halmshaw, 6.30 p.m.

INSTITUTE OF REFRIGERATION

Thurs., Oct. 25th.—Junior Institution of Engineers, Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "Problems of Oil Separation in Refrigeration Equipment," I. F. Eyles, 5.30 p.m.

INSTITUTION OF BRITISH AGRICULTURAL ENGINEERS

Wed., Oct. 24th.—E. MIDLANDS CENTRE : Agricultural House, Lincoln, "World Trends in Agricultural Engineering," W. H. Cashmore, 7 p.m.——SCOTTISH CENTRE : Visit to Scottish Machinery Testing Station, Tea and Informal Meeting at Wee Windaes Restaurant, Edinburgh, 2.30 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

Sat., Oct. 20th.—MIDLANDS BRANCH : College of Technology, Loughborough, "The Manufacture and Industrial Uses of Hydrazine," W. S. Stevens and J. West, 3 p.m.

Tues., Oct. 23rd.—N.W. BRANCH : Grosvenor Hotel, Chester, "Fluidisation Applied to the Handling of Bulk Solids," D'Arcy Smith, 7 p.m.

INSTITUTION OF CIVIL ENGINEERS

To-day, Oct. 19th.—ASSOCIATION OF LONDON GRADUATES AND STUDENTS : Great George Street, Westminster, London, S.W.1, Graduates' and Students' Conversazione, 7.30–11.30 p.m.

Tues., Oct. 23rd.—ROAD MEETING : Great George Street, Westminster, London, S.W.1, "Skidding Resistance of Roads and the Requirements of Modern Traffic," C. G. Giles, 5.30 p.m.

Tues., Oct. 30th.—HYDRAULICS MEETING : Great George Street, Westminster, London, S.W.1, Symposium on Side Spillways, General Reporter P. O. Wolf ; "A Theoretical Consideration of Side Weirs as Storm Overflows," Peter Ackers ; "The Discharge of Water Over Side Weirs in Circular Pipes," J. W. Allen ; "The Discharge Capacity of Side Weirs," V. K. Collinge ; "The Behaviour of Side Weirs in Prismatic Channels," Wm. Frazer, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

To-day, Oct. 19th.—EDUCATION DISCUSSION CYCLE : Savoy Place, London, W.C.2, Discussion on "Experiments for the Electronics Laboratory," opened by V. Attree, 6 p.m.

Mon., Oct. 22nd.—RADIO AND TELECOMMUNICATION SECTION : Savoy Place, London, W.C.2, Informal Evening on "The Use of Transistors in Radio and Television," talks by A. J. Biggs and E. Wolfendale, 5.30 p.m.

Tues., Oct. 23rd.—MEASUREMENT AND CONTROL SECTION : Savoy Place, London, W.C.2, Discussion on "The Use of Electronic Computers in Nuclear Reactor Design Studies," opened by R. W. Sutton, 5.30 p.m.

Wed., Oct. 24th.—SUPPLY SECTION : Savoy Place, London, W.C.2, Chairman's Address, "Engineering Efficiency, Economics and Expediency," P. J. Ryle, 5.30 p.m.

Thurs., Oct. 25th.—ORDINARY MEETING IN CONJUNCTION WITH THE BRITISH NUCLEAR ENERGY CONFERENCE ; UTILISATION SECTION PAPER : Savoy Place, London, W.C.2, Conduction and Induction Pumps for Liquid Metals," L. R. Blake, 5.30 p.m.——S.W. SCOTLAND SUB-CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "An Introduction to Computers," P. A. V. Thomas, 7 p.m.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND

Tues., Oct. 23rd.—39, Elmbank Crescent, Glasgow, "Some Unsolved Problems of Ship/Model Correlation," A. M. Robb, 6.30 p.m.

INSTITUTION OF LOCOMOTIVE ENGINEERS

Wed., Oct. 24th.—GENERAL MEETING : Institution of Mechanical Engineers, 1, Birdcage Walk, London, S.W.1, "Experiences with Diesel Railcars," M. J. Devereux, 5.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, Oct. 19th.—GENERAL MEETING : 1, Birdcage Walk, Westminster, London, S.W.1, Presidential Address, "Motive Power on Sea and Land," T. A. Crowe, 6 p.m.——SCOTTISH A.D. CENTRE : Robert Gordon Technical College, Aberdeen, "Sales and Service in the Transport Industry," J. M. Forbes, 7.30 p.m.

Sat., Oct. 20th.—LONDON GRADUATES' SECTION : Visit to London Transport Railway Depot, Ruislip, 9.45 a.m.

Tues., Oct. 23rd.—EDUCATION GROUP DISCUSSION : 1, Birdcage Walk, Westminster, London, S.W.1, "A Review of Exchange Arrangements for Engineering Students," 6.45 p.m.——EASTERN BRANCH : Good Companions Hotel, Slough, "The Engineer's Contribution to the Conservation of Natural Resources," Sir Harold Hartley, 7.30 p.m.——S. WALES BRANCH : Royal Institution of S. Wales, Swansea, "The Pressurised Water Reactor as a Source of Heat for Steam Power Plants," J. M. Kay and F. J. Hutchinson, 6 p.m.

Wed., Oct. 24th.—SOUTHERN BRANCH : Visit to No. 6 (Veh.) Trn. Bn., R.E.M.E., Havannah Barracks, Bordon, Hants, 2.15 p.m.——YORKSHIRE BRANCH : The University, St. George's Square, Sheffield, "Hydraulic Accumulators," J. G. Frith, 6.30 p.m.

Thurs., Oct. 25th.—BRITISH NUCLEAR ENERGY CONFERENCE MEETING : Institution of Electrical Engineers, Savoy Place, London, W.C.2, "Conduction and Induction Pumps for Liquid Metals," L. R. Blake, 5.30 p.m.

Fri., Oct. 26th.—GENERAL MEETING IN CONJUNCTION WITH THE APPLIED MECHANICS AND LUBRICATION GROUPS : 1, Birdcage Walk, Westminster, London, S.W.1, "Principles and Applications of Hydro-dynamic Type Gas Bearings," G. W. K. Ford, D. M. Harris and D. Pantall, 6 p.m.

INSTITUTION OF NAVAL ARCHITECTS

Tues. and Wed., Oct. 23rd and 24th.—JOINT MEETING WITH THE INSTITUTE OF MARINE ENGINEERS : 85, Minories, London, E.C.3, Symposium, "Fires in Ships," 10.30 a.m., Wednesday, Members' All-Day Visit to Portsmouth.

INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Wed., Oct. 24th.—INFORMAL MEETING : Conference Room, 4th Floor, Waterloo Bridge House, London, S.E.1, Vice-Chairman's Address, "The Main Line Transmission Plan and Performance," A. J. Jackman, 5 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

Tues., Oct. 23rd.—WALES AND MONMOUTHSHIRE BRANCH : S. Wales Institute of Engineers, Park Place, Cardiff, "Modern Steelwork Fabrication," G. E. Cooper, 6.30 p.m.

Thurs., Oct. 25th.—11, Upper Belgrave Street, London, S.W.1, "A Review of the Structural Steelwork in the 'Seraphim' Extensions at Appleby-Frodingham," S. Richards and N. Lancaster, 5.55 p.m.

Fri., Oct. 26th.—MIDLAND COUNTIES BRANCH : James Watt Memorial Institute, Great Charles Street, Birmingham, Chairman's Address, R. J. Fowler, 6 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, Oct. 19th.—INFORMAL MEETING : Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "Oil Additives," S. E. Holmes, 7 p.m.

Fri., Oct. 26th.—ORDINARY MEETING : Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "Rubber and the Process of Manufacture," F. Skelton, 7 p.m.

MANCHESTER ASSOCIATION OF ENGINEERS

Fri., Oct. 26th.—Engineers' Club, Albert Square, Manchester, "John Rennie, 1761–1821, a Study of the Life and Work of an Engineer in Georgian England," C. T. G. Boucher, 6.45 p.m.

ROYAL AERONAUTICAL SOCIETY

Tues., Oct. 23rd.—SECTION DISCUSSION : 4, Hamilton Place, London, W.1, "Functional Efficiency of Aircraft," introduced by C. Abell and A. F. Hutton, 7 p.m.

ROYAL INSTITUTION OF CHARTERED SURVEYORS

Thurs., Oct. 25th.—Town Hall, Katharine Street, Croydon, Surrey, a mock "Hearing Before a Valuation Court," devised by Philip Bean and Arthur Lockwood, 6 p.m.

ROYAL INSTITUTION OF GREAT BRITAIN

Tues., Oct. 23rd.—21, Albemarle Street, London, W.1, "Optics in Industry," No. II, "Composition," A. G. Menzies, 6 p.m.

Fri. Oct. 26th.—21, Albemarle Street, London, W.1, "Diamonds, Meteorites and the Origin of the Solar System" Harold C. Urey, 9 p.m.

SOCIETY OF INDUSTRIAL RADIOLOGY

Fri., Oct. 26th.—British Institute of Radiology, 32, Welbeck Street, W.1, "Welding and Inspection of High-Pressure Pipes," J. H. Webborn, 7 p.m.

SOCIETY OF INSTRUMENT TECHNOLOGY

Tues., Oct. 30th.—JOINT MEETING WITH CONTROL SECTION : Manson House, Portland Place, London, W.1, "Control Engineering and the Automatic Process Plant," D. S. Townend, 6.30 p.m.

WEST OF SCOTLAND IRON AND STEEL INSTITUTE

To-day, Oct. 19th.—39, Elmbank Crescent, Glasgow, Symposium on the Application of Low-Alloy Steels for Welded Pressure Vessels, 10 a.m.